THE RED-THROATED LOON AS AN INDICATOR OF ENVIRONMENTAL QUALITY IN THE BEAUFORT SEA REGION: AN INTERIM REPORT

by
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Edmonton, Alberta

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The data in this report are preliminary and should not be cited without the permission of the author.

EXECUTIVE SUMMARY

The objective of this project is to monitor the effect of future offshore oil and gas development on the birds that use the coastal areas of the Beaufort Sea. A preliminary investigation in 1984 indicated that the Red-throated Loon would be a suitable indicator species for monitoring due to its vulnerability to the proposed development, its abundance in the Beaufort Sea region and the conspicuous nature of its nests and chicks. The parameters chosen to be monitored each year were the abundance of Red-throated Loon pairs, their breeding effort and breeding success.

Five study plots were established in 1984: Atkinson Point and King Point where port development had been proposed (Dome, ESSO, Gulf 1982), Nuvorak Point where future shoreline development was unlikely (control for impact of shoreline development), Husky Lakes which would be unaffected by oil spills in the Beaufort Sea (control for impact of oil and other pollutants in the Beaufort Sea), and Toker Point which was relatively inexpensive to access from Tuktoyaktuk, hence suitable for a more intensive study of the Red-throated Loon.

This is a report on the first four years of the predevelopment phase of the study. This along with one more year of data will provide a benchmark for monitoring once full scale development has occurred.

From 1985 to 1988, every wetland in each of the five study plots was searched to obtain total counts of Red-throated Loon pairs, nests, eggs and chicks. The surveys were conducted by helicopter, with the exception of several surveys at Toker Point which were done by foot.

The same methods were used for the preliminary investigation in 1984, although the boundaries of three of the study plots were slightly different.

A field camp was established at the Toker Point study plot from mid-June to early September each year to conduct a more intensive study that would improve our ability to interpret the results of the basic monitoring program. Information was collected on the type of habitat used by nesting loons, the mortality rate of loon eggs and chicks, the timing of nest initiation, hatch and fledging, and the rate of development of the eggs and chicks. Information was also gathered on the various factors which might affect the productivity of the loon: weather; timing of break-up and freeze-up; water-levels in the wetlands; species and abundance of fish in loon feeding areas; frequency of feeding the chicks; abundance of predators; and abundance of prey other than loon eggs and chicks for the predators. The better our understanding of how various environmental and biological factors affect the indicator species under undisturbed conditions, the easier it will be to differentiate between man-caused and natural fluctuations in productivity during the post-development phase of the study.

The density of Red-throated Loon pairs occupying territories ranged from 0.48 pairs/km^2 to 1.92 pairs/km^2 with the highest densities occurring on the Tuktoyaktuk Peninsula and the lowest at King Point. The number of pairs of loons at each study plot did not change significantly over the duration of the study, except at Nuvorak Point. There the number of pairs increased, with the largest influx occurring in 1987.

Productivity of the Red-throated Loons averaged 0.66 fledged young per nesting pair from 1985 to 1988. In comparison, studies elsewhere have reported productivity ranging from 0.35 fledged young per pair on Shetland (Bundy 1978) to 1.15 fledged young per pair in Finland (Lokki and Ekløf 1984).

As expected in an arctic environment, the breeding effort and success of the Red-throated Loon fluctuated from year to year. The percentage of resident pairs that attempted to nest varied from 58% in 1986 to 87% in 1984; similarly, the percentage of breeding pairs that were successful varied from 46% in 1986 to 72% in 1984.

The primary factor that affected breeding effort was the timing of thaw of the small ponds used by the Red-throated Loon for nesting. Although an early thaw had very little effect on breeding effort, the two-week late thaw in 1986 coincided with a much lower breeding effort. Only 58% of the Red-throated Loon pairs in the study area nested in 1986, compared to 73% to 78% in other years.

Predator pressure, particularly by arctic foxes, was the main influence on hatching success. The hatch at Toker Point was lowest in 1987 when the fox population peaked and highest in 1988 following a crash in the number of foxes during the winter. To a lesser extent, hatching success was also influenced by the amount of food other than loon eggs and chicks available for the predators.

Chick survival was fairly constant in all years but 1988 when it dropped by about half. The higher mortality rate of loon chicks in 1988 was attributed primarily to heavier predation by avian predators, for it

coincided with a significant increase in the number of avian predator chicks, particularly Glaucous Gulls. A four-day storm with rain, snow and winds over 50 kph in early August may have also contributed to the death of several loon chicks in 1988.

Adult Red-throated Loons brought an average of 8.3 fish to each chick per day. There was no significant difference in the feeding rate from one year to the next, nor was there any significant change in the frequency of feedings as the chicks got older.

The annual fluctuations in breeding effort and hatching success of waterfowl at Toker Point followed the same pattern as those of the Red-throated Loon, which is further evidence of the suitability of the Red-throated Loon as an indicator species.

The Red-throated Loon exhibited a strong tendency to use the same territory each year. At Toker Point 57% of the territories (n=61) were occupied in all four years of the study, while only 20% were used just one year. Breeding success had no effect on whether a territory was reused the following year.

In order to determine the optimum time to survey for incubating loons, two methods of establishing the date when the eggs were laid were tried: by floating the egg in water, and by weighing and measuring the size of the egg. Using the floatation method, one could estimate the age of the egg within 4 days, whereas the 95% Confidence Interval for the age derived from weighing and measuring the size of an egg was approximately ±7 days. Since neither method of aging ages was very accurate and both involved disturbing the nest, it is recommended that

the timing of the surveys for incubating loons be based on the timing of thaw of the nest ponds. In years when the timing of spring thaw was typical or late, the loons nested an average of 17 days after the nesting ponds thawed. In a year when the ponds thawed early, the timing of egg-laying depended on when the loons arrived in the region.

Very few chicks died after three weeks of age. Based on this, as well as the time of hatch and fledging, it was determined that most years the best time to conduct the aerial surveys for chicks near fleding would be from 18 to 22 August.

The Red-throated Loon arrives in the Beaufort Sea region in late May and early June. Most years its nesting ponds thaw at the same time and are occupied immediately by pairs of loons. With the exception of 1986 when spring was two weeks late, egg laying began in mid-June and was completed by the first week in July with a mean date of lay between 21 and 25 June. The eggs were laid 2 to 3 days apart (n=4), usually hatched 1 day apart (n=7), and were incubated 24 to 27 days (n=13). The chicks fledged from late August to mid-September following a development period of 43 to 52 days (n=10).

Lost clutches of eggs were replaced 26 to 40% of the time at Toker Point. The earlier the spring thaw, the greater the proportion of renests. An average of 10 days lapsed between loss of the first clutch and laying the replacement clutch (n=10). Breeding success from replacement clutches was low, ranging from 0.38 young per pair in 1985 to none in 1986.

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1.0 INTRODUCTION

Exploration for oil and gas in the Beaufort Sea has resulted in the discovery of substantial quantities of fossil fuel. Although recent low market prices for oil have caused a slow-down in exploration activity in northern Canada, with favourable economics full scale extraction of oil and gas from the Beaufort Sea region can be expected.

Oil and gas production in the Beaufort Sea may have a significant impact on migratory bird populations. Since much of the oil and gas reserves are offshore, a large portion of the associated development, including ports, airstrips, staging areas, accommodations, processing plants and communication towers, will likely occur along the coastline. Likewise, most of the bird species that inhabit the Beaufort Sea region concentrate in the coastal areas: notably the Brant, Greater White-fronted Goose, Oldsquaw, White-winged Scoter, Surf Scoter, scaup sp., Common Eider, Red-throated Loon, Arctic Tern, Glaucous Gull and several species of shorebirds. Potential impacts of oil and gas extraction on bird species in the Beaufort Sea region can be categorized as follows:

- mortality due to oil pollution from either catastrophic or chronic oil spills,
- habitat loss or degradation due to construction and operation of facilities such as ports, airstrips, roads, accommodations and pipelines, and
- disturbance from activities related to oil and gas extraction (for example, aircraft, ship and vehicular traffic, and recreational activity)

In view of the vulnerability of birds to offshore oil and gas extraction in the Beaufort Sea, the Canadian Wildlife Service decided to monitor the impact of the proposed development on the birds in the region. The results of a preliminary study conducted in 1984 showed that the Red-throated Loon would be a suitable "indicator species" for the proposed monitoring project. The Red-throated Loon occurred in relatively high densities on both the Tuktoyaktuk Peninsula and the coastal plain in northern Yukon, so that changes in numbers or productivity could likely be detected statistically. Red-throated Loons were present in the Beaufort Sea from June to September, nested near the coast and fished daily in the Beaufort Sea; hence, they would be vulnerable to both oil spills and development along the coastline. The adults, young and nests were all conspicuous enough that they could be located from the air using a helicopter. Finally, Red-throated Loons tend to use the same nesting territory year after year (Davis 1972; Bergman and Derksen 1977; Gomersall 1986), which would facilitate locating the nests throughout the study.

To monitor the impact of development, the following parameters were measured each year:

a) number of resident pairs of Red-throated Loons,

b) breeding effort (the proportion of pairs that laid eggs), and

c) breeding success (the number of young just prior to fledging per active nesting territory).

These data have been gathered for four years and will be collected one more year to determine the natural fluctuations in the breeding

population size and productivity prior to development. Thereafter, the data will be collected once every five years, or following major development or an oil spill thought to be a threat to regional bird populations. The data collected later in the study will be statistically tested to see if the values fall within the range of those obtained during the predevelopment phase of the study.

For a monitoring study to be successful, it is vital to understand how various environmental and biological factors affect the indicator species under undisturbed conditions. This understanding is necessary in order to differentiate between man-caused and natural fluctuations that could occur during the post-development phase of the study. Thus, the monitoring study has a second objective which is to understand the factors that cause the natural annual fluctuations in productivity of the indicator species. Hence, information is being gathered on each of the following: daily weather; timing of break-up and freeze-up; water-levels in the wetlands used by Red-throated Loons; location of the marine feeding areas; species and abundance of fish in the feeding areas; species and size of fish fed to the chicks; frequency of feeding the chicks; abundance of predators; and abundance of prey other than loon eggs and chicks for predators.

2.0 METHODS

2.1 Aerial surveys

During the preliminary study in 1984, the following five study plots were selected based on loon densities, the likelihood of oil and

gas related development at that location, and accessibility from Tuktoyaktuk:

- Atkinson Point (69°55'N; 131°20'W), where a medium draft port to support future oil and gas activity had been proposed (Dome, Esso, Gulf 1982),
- King Point (69°05'N; 138°00'W) west of the Mackenzie Delta where a deep draft port had been proposed (Dome, Esso, Gulf 1982),
- Nuvorak Point (70°03'N; 30°45'W) where future shoreline development was unlikely (control area for the impact of shoreline development),
- Husky Lakes (69°10'N; 132°55'W) which would be unaffected by a major oil spill in the Beaufort Sea (control for the impact of oil and other pollutants in the Beaufort Sea), and
- west of Toker Point (69°37'N; 132°44'W) which was relatively inexpensive to get to from Tuktoyaktuk and where no development had been proposed to date (site chosen for a more intensive study of the Red-throated Loon).

Figure 1 shows the location and extent of each of these five study plots.

Each study site was searched twice in 1985: once for Red-throated Loon nests during the incubation period, then later for chicks over two weeks old. The surveys were repeated from 1986 to 1988, but instead of only one survey for eggs, two were conducted about 12 days apart. It was evident from the 1985 surveys that a second search for eggs was necessary, because of the three week spread in egg laying

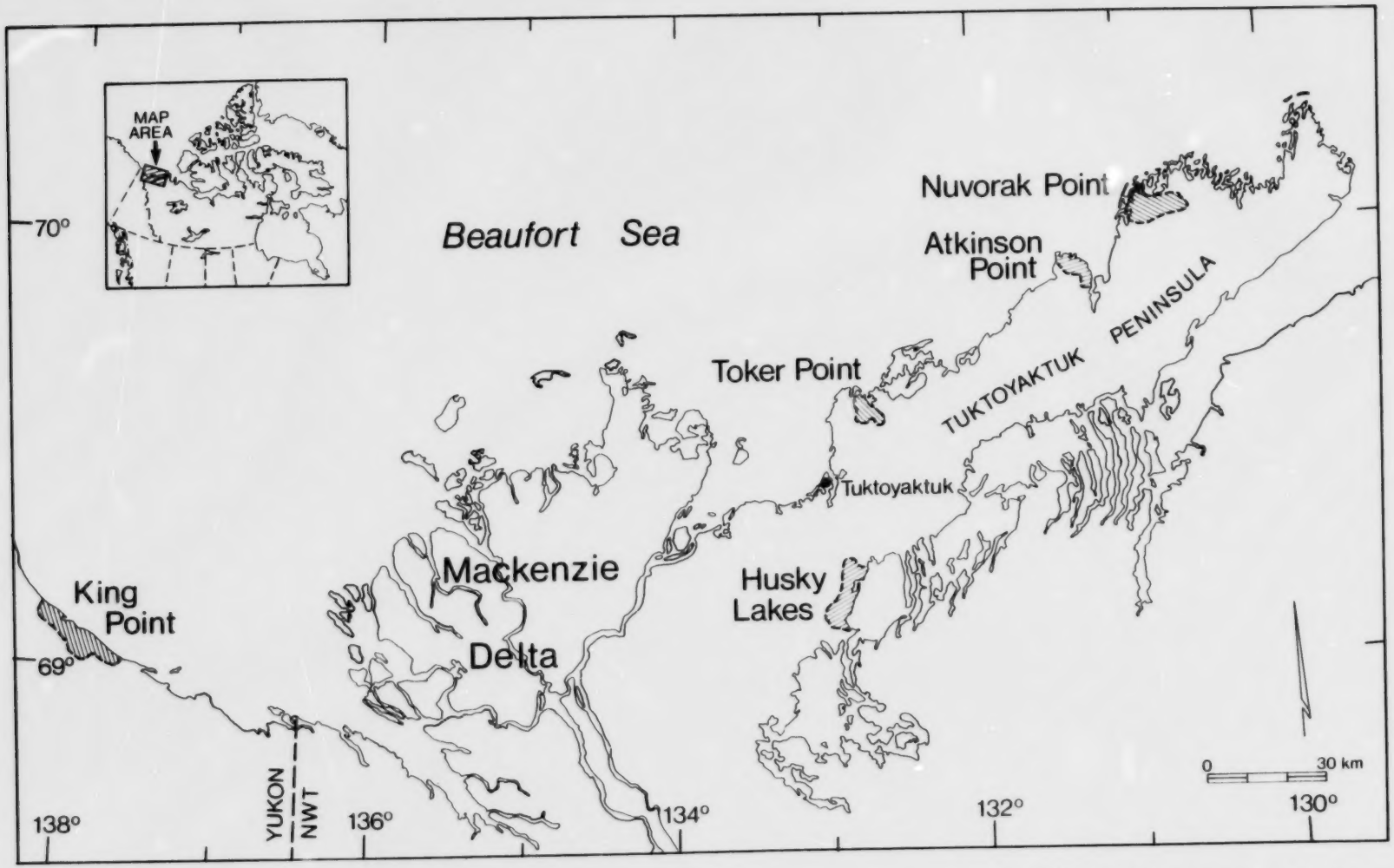

Figure 1. Location of the five study plots selected for monitoring the productivity of the Red-throated Loon in the Beaufort Sea region.

and because of egg predation. Data on incubating loons and their chicks were also collected, during the preliminary study in 1984, at all but the King Point study plot. Although the boundaries of the Nuvorak Point and Husky Lakes study plots were slightly different in 1984, data from these plots have been included in the appropriate analyses.

The searches for nests were conducted by two observers in a Bell 206 Jet Ranger helicopter except at Toker Point from 1985 to 1987 when surveys were done by foot. In order to locate incubating loons, all wetlands within each study area were checked by flying over the ponds at 70 to 90 ft above ground level (agl) at 30 to 60 mph. Wherever there were many small ponds or other complex but suitable habitat, the survey helicopter proceeded more slowly. When a loon was sighted, the shoreline of the pond was checked for a nest by hovering at about 25 ft agl and slowly moving sideways around the edge of the pond. If a loon was seen on a pond, the pond was considered an occupied territory unless there was evidence to the contrary: for example, if the loon had just flushed from a nearby occupied territory or if the habitat was deemed unsuitable.

Each territory was numbered and the location was marked on a 1:50 000 scale topographical map. The number of loons, number of nests (old nests were distinguished from nests that had either been built or renovated that year), and number of eggs were recorded on a cassette tape recorder. The reaction of each loon to the helicopter (response and distance at which the loon responded) was also recorded. Photographs of the nest site and pond were taken using a camera with a

28 mm lens and shutter speed of 1/250 sec. Prior to each aerial survey, the date, time of day, pilot, observers, and weather (temperature, wind speed and direction, cloud cover, precipitation and visibility) were recorded. All data were transcribed onto a computer form later the same day.

Using 1:50 000 scale maps and airphotos, the following was determined for each nesting territory:

- the mercator grid number;
- the orientation of the pond;
- number of potential alternate ponds within 200 m;
- the distance to the nearest marine feeding area; and
- the distance to the nearest territory occupied by another pair of Red-throated Loons.

About four weeks after the mean date of hatch, each study plot was resurveyed to determine the number of young loons prior to fledging. As in the June/July surveys, the Toker Point study plot was searched on foot from 1985 to 1987, whereas a Bell 206 helicopter was used for all other surveys. All of the wetlands were checked at approximately 30 mph at 100 ft agl. At each of the ponds known to be active nesting territories, if no young were seen, the helicopter passed over the pond again at about 10 mph and 10 ft agl to ensure the chicks were not hiding in the emergent vegetation during the first pass. If still no young were seen, the helicopter climbed to 300 ft and circled or hovered over the pond for about a minute to see if any young loons surfaced from underwater. If not, it was assumed that there were no

survivors from that nest. At each nesting territory, we recorded the number of adults and young, the approximate size of each young loon relative to adult size, and the reaction of each loon to the helicopter. A photograph of the pond was taken from the helicopter when directly above the pond. Any new nesting territory missed during the previous surveys was assigned a number, described and located on a 1:50 000 scale map.

In years when funds were available, additional aerial surveys were conducted in September to determine the approximate date when the young loons fledged. The number of adults and amount of ice on the ponds was also recorded during these surveys.

Most of the ponds used by the Red-throated Loon for nesting were so small that their size could not be determined with accuracy from the aerial photographs available. Thus, photographs of the ponds were taken from the helicopter at a fixed height (300, 400 or 500 ft agl) directly above the pond using a camera with a 50 mm lens and 100 ASA print film. From the same height, a photograph was also taken of a marker of a known length on the ground to provide a scale for the photographs so that the area of each pond could later be calculated.

Following the July 1984 aerial survey for incubating loons and the August 1985 aerial survey for chicks, the Atkinson Point plot was resurveyed by two observers on foot to check the accuracy of the aerial surveys.

2.2 Ground surveys

From 1985 to 1988, field studies were conducted at the Toker Point study plot from June to the September (Fig. 2). During the preliminary study in 1984, similar ground surveys were conducted at the Atkinson Point plot in June and July.

Starting in mid-June, each wetland within the study area was searched for Red-throated Loons every three to five days. Any pond with a pair of Red-throated Loons was assigned a nesting territory number and marked on a 1:50 000 scale map. The loons were observed from a concealed place at a distance for 15 to 20 min to determine whether they had begun to nest. If the loons were not nesting, they generally drifted on the pond and slept. Loons which had started to nest usually appeared more alert and resumed nest construction, egg laying or incubation within about 10 min of being disturbed.

In 1985 and 1986, once a loon had started to incubate, we approached the nest and recorded the number of eggs. If no eggs or only one was found, the nest was checked every day until there were two eggs (the normal clutch size) in order to establish laying dates. Once the clutch was complete, the nest was checked every five days until near the time of hatch. Then it was visited daily to establish the precise date of hatch. At each visit, the date, time of day, number of eggs, number of adults present and their reaction to the observer (response and distance when reacted) were recorded.

Nest checks were discontinued in 1987 and not done in 1988, since approaching the nests seemed to result in increased predation of

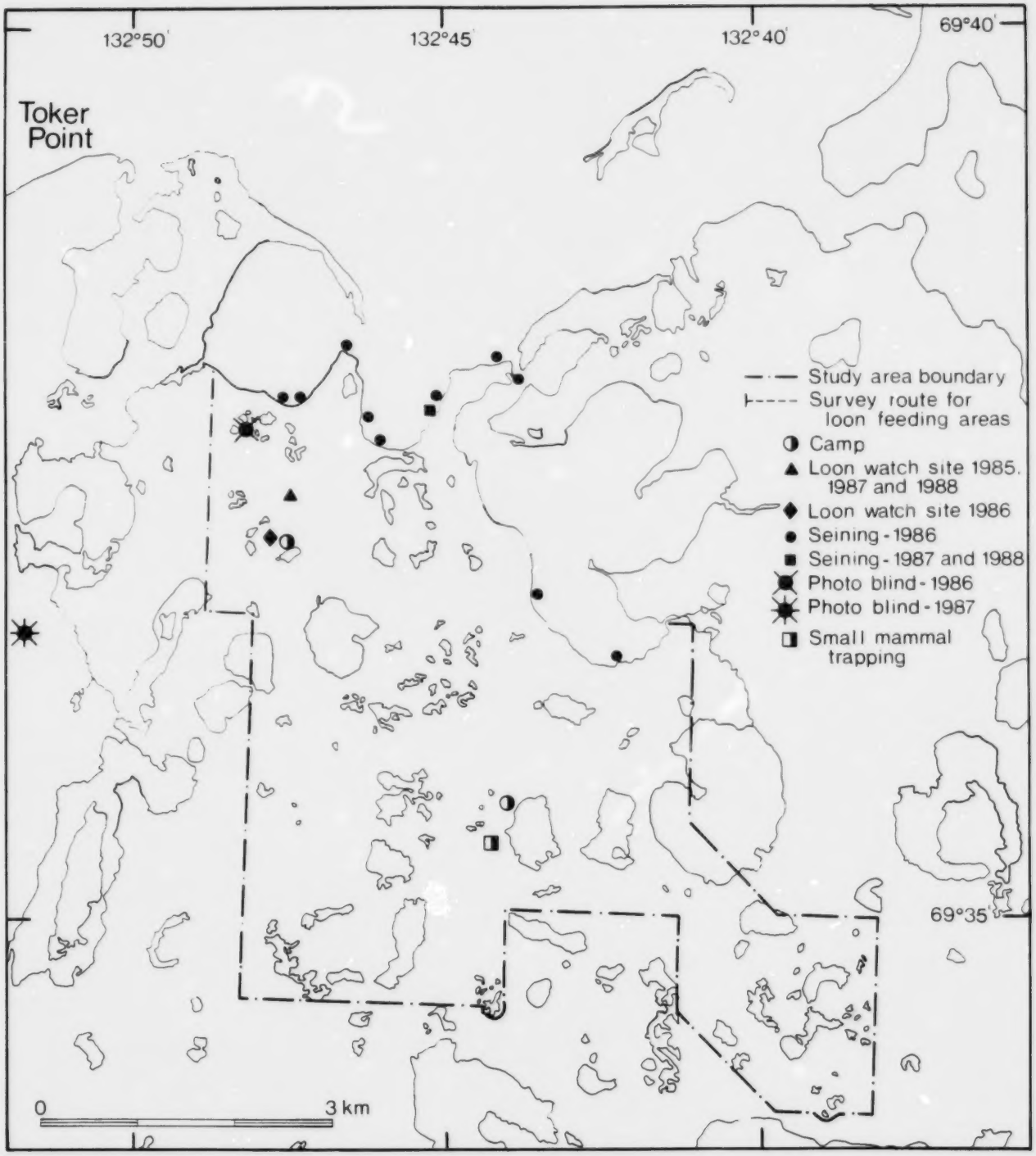

Figure 2. Toker Point study plot where ground surveys were conducted daily throughout the breeding season from 1985 to 1988.

the eggs and newly hatched chicks. Nesting and hatching data were still collected, but from a distance. In all four years, the location of the nest on the pond was sketched to facilitate locating the nest again and to establish whether the same nest site was used in future years.

At each visit during incubation in 1985 and 1986 and to a lesser extent in 1987, the density of the eggs was determined, both by weighing the eggs and by floating them in water. A Pesola 100 gm scale was used to weigh the eggs. The length and width of each egg was measured, then egg densities were calculated as described by Furness (1981):

$$\text{density} = \text{weight}/0.507 \times \text{length} \times \text{width}^2$$

For the floatation method of determining the density of the eggs, a small clear plastic container filled with lukewarm water was used. During the first stages of egg development, the angle at which the egg rested on the bottom was recorded. To assist in estimating this angle, 22°, 45°, 68° and 90° angles were etched into the plastic container. During the latter stages of development, when the egg floated to the surface, the height the egg floated above the surface, as well as the approximate diameter of the egg protruding at the surface and the angle of the egg were recorded. Millimetres were etched along a vertical and a horizontal line on the container to facilitate taking these measurements. After floating the eggs, they were dried thoroughly with a cloth to minimize chilling, then returned to the nest.

If a nest had been preyed upon, any sign of what had happened was noted, as well as the date. The nest territory was then rechecked approximately every five days until the beginning of August to see if a second clutch had been laid.

Once the eggs hatched, each nesting pond was visited every five days until near the time of fledging. Then the pond was visited daily to establish the exact date when the young departed from the nesting territory.

At each visit after hatch the following information was recorded: the date, time of day, number of adults, number of young, response of the adults and young to the observer (reaction and distance at which they reacted) and the amount of ice on the pond. In addition, plumage development and the size of chicks of known age were described in order to devise a system for aging the chicks.

Daily sightings of avian predators (gulls, jaegers, ravens, cranes, owls, hawks) were plotted on 1:50 000 scale maps to determine the total number of predators with hunting territories in the Toker Point study plot during June and July. Arctic fox dens were also located and their degree of use recorded.

Each active nesting territory in the Toker Point study plot was described in mid summer as follows:

- length, width and depth of pond;
- pond orientation, bottom type and turbidity;
- wetland type (basin complex, thermokarst, isolated pond, other);
- if a large pond, whether it was divided into distinct bays, hence had potential for several loon territories;
- number of nearby ponds (ponds within 200 m that could be used as alternate ponds);

- amount and species of emergent vegetation;
- amount of wet versus dry shoreline and the dominant species of vegetation along the shore;
- location of nest on pond (point, island (dimensions of island), offshore, dry shoreline, wet shoreline);
- plant species beside nest;
- visibility from nest;
- distar from nest to edge of pond;
- distance from nest to dry shore;
- distance from nest to open water;
- nest material;
- dimensions of nest (length, width and height above water); and
- nest type (platform, built-up or depression).

For comparison, 50 waterbodies th t had not been occupied by Red-throated Loons during the study were randomly selected and described using the same methods as above.

In addition to the pond depths measured during the pond descriptions, general descriptions and photographs of several wetlands were taken to compare water-levels from one year to the next.

Each year, an observation tent was used to monitor the parental behavior of a pair of loons with a chick (Fig. 2). The loons were observed for two of every four hours over a 24-hour period (from 5-7:00; 9-11:00; 13-15:00; 17-19:00; 21-23:00; 1-3:00) about twice a week between time of hatch and fledging. The date, time of day, weather, visibility and number of loons at each nesting territory were noted

prior to each watch. During the watch, the time and direction of all flights in and out of each nesting territory were noted, as well as whether the bird had a fish and the fate of the fish. During the first watches when the adults were still brooding the young, the length of time spent brooding was recorded. From 1986 to 1988, behavior such as territorial displays was also recorded.

In order to determine the size and species of fish being fed to the chicks, photographs of adult loons feeding their young were taken from a blind placed at the edge of a pond in 1986 and 1987. The scale in the photographs was determined by using the distance from the anterior edge of the eye to the tip of the bill which had been measured on 22 Red-throated Loon specimens from the National Museums of Canada. A 500 mm lens and 1.5 x converter were used to photograph the fish.

Approximately 10 km of coastline were walked repeatedly between mid-July and early September from 1985 to 1987 to record the number and location of Red-throated Loons feeding in marine waters (Fig. 2). In addition, in 1985 and 1987, we watched loons on several coastal lakes to see if they ever fed in freshwater. It was assumed that fish inhabited any of the lakes that were connected to the ocean by a stream (Mike Lawrence, Fisheries Biologist, Department of Fisheries and Oceans, pers. comm.).

About once a week from mid-July until the end of August from 1986 to 1988, a beach seine was used to catch fish in areas where the Red-throated Loon fed in order to determine the species and abundance of fish available to the loons. Two people dragged a 10 m long net

parallel to the beach for 25 m (some hauls in 1986 were 15 m long). In 1987 and 1988, seining occurred once every 2 h over a 12 h period and always at the same location (Fig. 2). In 1986, seining was done at several different sites, and although six hauls were made at each site, they were consecutive rather that at 2 h intervals. Prior to each haul, the water temperature was taken. The fish caught were identified, counted and measured for their fork length (total length for sculpins and flounders). All fish were returned to the sea immediately except some that were less than 50 mm long which we could not identify. These were placed in a 10% formalin solution and later identified in the Fisheries and Oceans laboratory in Tuktoyaktuk.

The weather was recorded daily throughout the field season (temperature, wind speed and direction, cloud cover, cloud type, and precipitation). We also recorded the timing of thaw of the marshes, ponds, lakes and nearshore ice in spring, and the occurrence of ice on the marshes and ponds in autumn.

Samples of Red-throated Loon eggs, adults and young-of-the-year were collected outside the study plots on the Tuktoyaktuk Peninsula to be used as references for future environmental contaminants. The egg yolk and albumen were placed in a clean glass jar which had been rinsed with acetone. The lid of the jar was lined with aluminum foil to prevent contamination and the contents were frozen later the same day. The egg shells were placed in a non-crushable container and were frozen. Adults and young loons were collected with a .22 calibre rifle, placed in plastic bags and frozen the same day. The adults were taken prior to nest initiation, whereas the chicks were taken just before fledging.

Fish, the size used by the Red-throated Loon to feed their young, were also collected in 1986. They were obtained with a seine net, place in plastic whirlpaks and frozen the same day.

The nesting territories of all Pacific Loons within the Toker Point study plot were assigned a number and marked on a 1:50 000 scale map. Although Pacific Loon territories were not systematically searched for nests, each territory was checked once a week and any evidence of nesting, such as a loon getting off a nest or the presence of a chick, was recorded.

A daily record was kept of the number of sightings of all bird species. Every nest and brood found within the study area was marked on a 1:50 000 scale map. The number of eggs or young was noted and the nest site was described. This report presents the relative abundance of the species known to eat loon eggs and chicks (jaegers, gulls, cranes, ravens, hawks and owls) and of alternate prey (especially waterfowl). See Sirois and Dickson (1989) for a more detailed account of the bird species found at Toker Point.

In 1987 and 1988, small mammals (ie. voles, mice, lemmings) were live-trapped to determine their relative abundance. In early July, a grid approximately 135 m square was established and 100 live-traps were set 15 m apart. The traps were checked twice a day for 10 days. Whenever a small mammal was caught, we noted the species, its condition, the date, time, and trap number. We then marked the small mammal between the ears with a blue felt pen so that it could be identified if it was recaptured.

3.0 RESULTS

3.1 Breeding success

3.1.1 All five study plots

Table 1 shows the dates when the surveys of incubating loons and young were conducted. Based on the results of these surveys, the density of occupied territories, active territories and nearly fledged chicks was calculated for each study plot in each year (Table 2; Appendix A). A site was designated as occupied if a loon was present during at least one survey, it was suitable loon nesting habitat, and it was unlikely part of a nearby loon territory. An active territory was one where we found evidence of nesting (eggs, chicks, fresh egg remains or a dead chick). A resident pair was a pair of loons that occupied a territory; a breeding pair was one that laid eggs; and a successful pair was one with young near fledging. A fledged young was one that could fly well enough that it vacated the nesting territory.

The density of territories occupied by Red-throated Loons ranged from 0.48/km^2 to 1.92/km^2 at the five study plots during the period from 1984 to 1988 (Table 2; Appendix A). The study plots at Toker Point and Atkinson Point consistantly had the highest density of loon pairs each year (five year averages of 1.72 and 1.26 pairs/km^2 respectively), whereas King Point on the Yukon coast had the lowest densities (four year average of 0.56 pairs/km^2). The number of occupied territories at each study plot did not change significantly over the duration of the study (X^2 tests, 3df, $p > 0.05$), except at Nuvorak Point. There the

Table 1. Dates surveys were conducted for incubating Red-throated Loons and for chicks near fledging from 1984 to 1988.

Year	Date of survey by area				
	Toker Point	Atkinson Point	Nuvorak Point	Husky Lakes	King Point
1984	26 June	3 July	25 June	5 July	
	21 August	23 August	22,23 August	24 August	
	30 August	30 August			
	5 September	5 September			
		12 September			
1985	1-9 July*	9 July	1,9 July	3 July	8 July
	10-14 August*	13 August	12 August	11 August	14 August
	3 September	3 September			
	10 September	10 September			
	17 September	17 September			
1986	5-8 July*	8 July	7 July	6 July	5 July
	17-20 July*	20 July	20 July	18 July	17 July
	25-27 August*	26 August	26 August	27 August	25 August
	9 September	9 September		9 September	
	17 September	17 September		17 September	
1987	28 June-2 July*	1 July	30 June	2 July	29 June
	10-15 July*	14 July	13 July	12 July	11 July
	18-20 August*	19 August	19 August	18 August	20 August
	6, 7 September*	9 September		9 September	
1988	30 June	30 June	28 June	27 June	29 June
	11 July	8 July	9 July	8 July	10, 11 July
	17, 18 August*	21 August	22 August	21 August	24 August
	6, 7 September*				

*Survey conducted by foot.

Table 2. Density of Red-throated Loon nesting territories and chicks near fledging at five study plots from 1984 to 1988.

Study plot	Plot size (km^2)	Density by study plot (no. per km^2)					
		Occupied territories[1]		Active territories[2]		Young near fledging	
		Mean	Range	Mean	Range	Mean	Range
Toker Point	26	1.72	1.62-1.92	1.38	1.04-1.50	0.89	0.31-1.96
Atkinson Point	33	1.26	1.06-1.45	0.97	0.64-1.27	0.91	0.42-1.39
Nuvorak Point[3]	65	0.87	0.68-1.08	0.63	0.43-0.82	0.37	0.14-0.62
Husky Lakes[4]	56	0.69	0.60-0.84	0.53	0.43-0.64	0.37	0.21-0.52
King Point[5]	96	0.56	0.48-0.67	0.38	0.26-0.46	0.32	0.22-0.42

[1]A territory was considered occupied if a loon was present during at least one survey, the site was suitable loon nesting habitat, and there was no evidence that the site was part of a nearby loon territory.
[2]A territory was considered active if there were eggs or young, or fresh egg remains or dead chicks.
[3]In 1984, 10 km^2 of Nuvorak Point study plot were not surveyed.
[4]In 1984, 4 km^2 of Husky Lakes study plot were not surveyed.
[5]In 1984, King Point study plot was not surveyed.

number of occupied territories increased (X^2 = 9.05, 3df, p=0.02), with the largest influx, of additional pairs of Red-throated Loons occurring in 1987 (Tables 3 and 4; Fig. 3).

The breeding effort of the Red-throated Loon varied both from year to year and from one study plot to the next (Tables 3 and 4; Fig. 4). Nest attempts were lowest in 1986 when an average of 58% of the loon pairs laid eggs, compared to 78% of the pairs in 1988 and 87% in 1984. These differences were significant at all but the King Point study plot (X^2 tests, 4df, $p < 0.05$; except at King Point where X^2 = 4.1, 3df, p=0.25). Throughout the study, the breeding effort was consistantly higher at Toker Point and Husky Lakes study plots than at the Nuvorak or King Point study plots; the average percentage of pairs that attempted to nest each year was 80%, 79%, 71% and 66% respectively (Fig. 4; Table 4).

Breeding success likewise varied between years and study plots (Tables 3 and 5; Fig. 4). The percentage of pairs that were successful was lowest in 1986 when an average of only 45% of the breeding pairs raised at least one young to near fledging, and highest in 1984 and 1985 when 72% and 63% respectively were successful. The difference in breeding success between years was significant at the Toker, Nuvorak and King Point study plots (X^2 tests, 3 to 4df, $p < 0.05$), and approached significance at Atkinson Point (X^2 = 7.9, 4df, p=0.09). Breeding success was most consistent from year to year at Husky Lakes study plot (X^2 = 3.36, 4df, p=0.50).

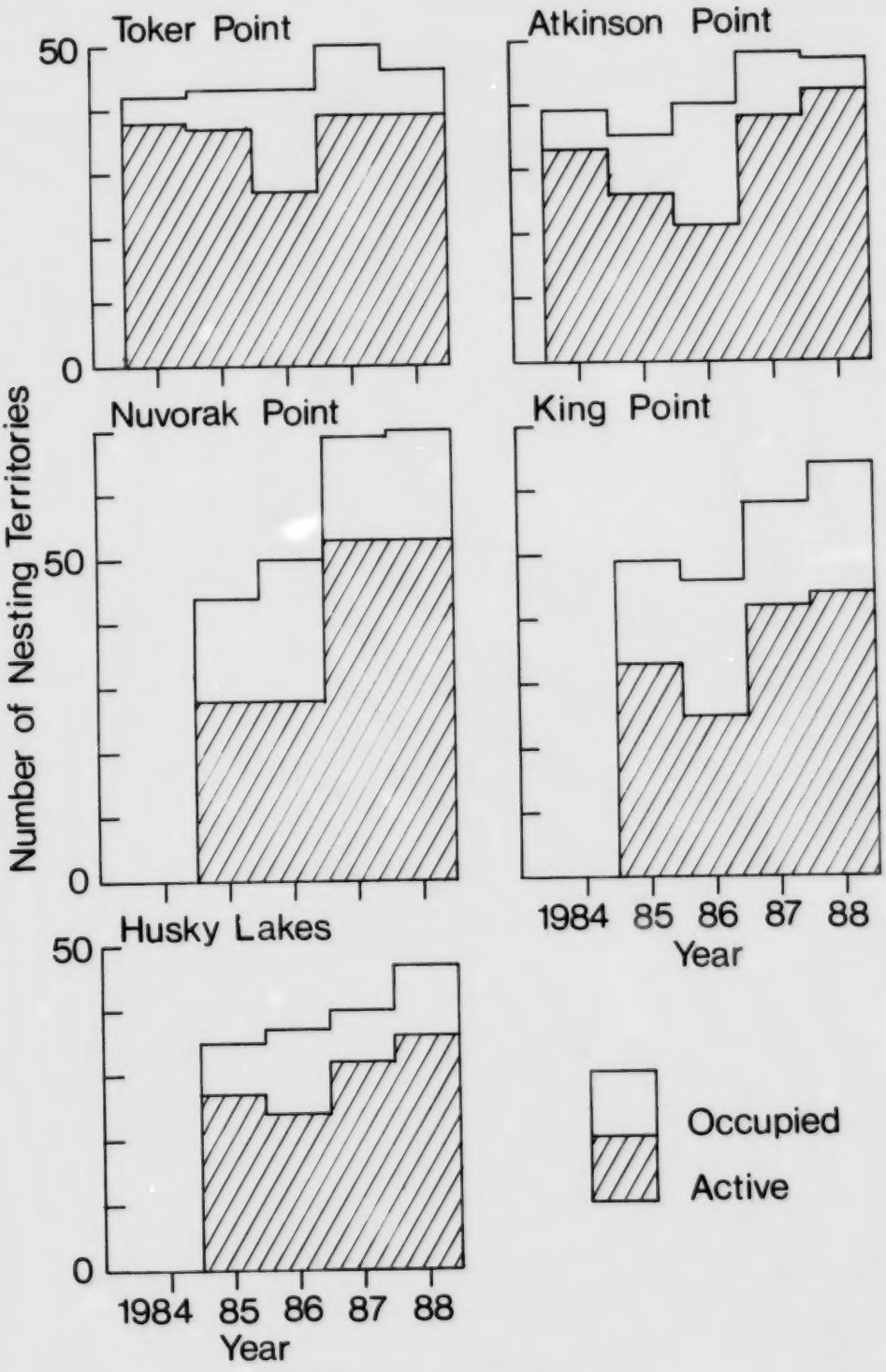

Figure 3. Number of Red-throated Loons that established nesting territories at each of the five study plots from 1984 to 1988.

Table 3. Summary of the breeding statistics for the Red-throated Loon at five study plots in the Beaufort Sea region from 1984 to 1988.

	Year				
	1984[1]	1985	1986	1987	1988
No. of pairs occupying territories	154	206	216	265	274
No. of pairs that laid eggs	134	151	125	204	214
% of pairs that attempted to nest	87%	73%	58%	77%	78%
No. of young that fledged	144	123	64	141	136
Percentage of breeding pairs that were successful	72%	63%	45%	49%	51%
Percentage of eggs that fledged	60%	50%	31%	40%	38%

[1]Data from 1984 based on only a partial survey.

Table 4. Breeding effort of the Red-throated Loon at five study plots in the Beaufort Sea region from 1984 to 1988.

	Plot size (km^2)	Year	No. of occupied territories	No. of active territories	Percentage of pairs that laid eggs[4]
Toker Point	26	1984	42	38	90
		1985	43	37	86
		1986	43	27	63
		1987	50	39	78
		1988	46	39	84
Atkinson Point	33	1984	39	33	85
		1985	35	26	74
		1986	40	21	52
		1987	48	38	79
		1988	47	42	89
Nuvorak Point[1]	65	1984	42	35	83
		1985	44	28	64
		1986	50	28	56
		1987	69	53	77
		1988	70	53	76
Husky Lakes[2]	56	1984	31	28	90
		1985	35	27	77
		1986	37	24	65
		1987	40	32	80
		1988	47	36	77
King Point[3]	96	1984	--	--	--
		1985	49	33	67
		1986	46	25	54
		1987	58	42	72
		1988	64	44	69

[1]In 1984, 10 km^2 of Nuvorak Point study plot were not surveyed.
[2]In 1984, 4 km^2 of Husky Lakes study plot were not surveyed.
[3]In 1984, King Point study plot was not surveyed.
[4]Difference between years is significant at all but King Point (X^2 tests, $p < 0.05$)

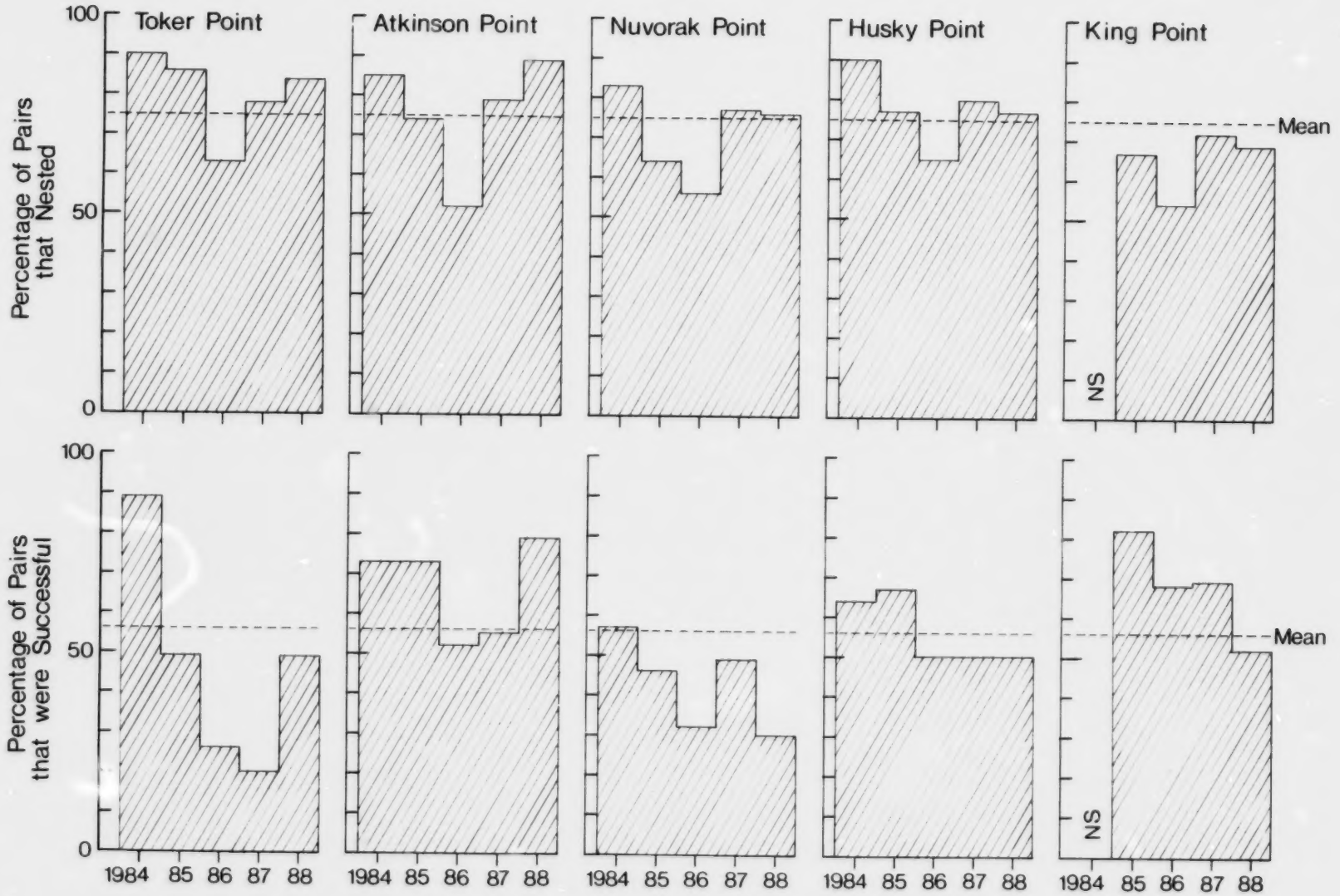

Figure 4. Breeding effort and success at five study plots in the Beaufort Sea region from 1984 to 1988 (dotted line indicates mean value).

Table 5. Breeding success of the Red-throated Loon at five study plots in the Beaufort Sea region from 1984 to 1988.

Study plot	Year	No. of eggs[1]	Ave. clutch size[2]	No. of young fledged[2]	Young fledged per active territory	Successful pairs (%)[3]
Toker Point	1984	67	1.96 (n=26)	51	1.34	34 (89)
	1985	64	1.80 (n=30)	24	0.65	18 (49)
	1986	48	1.81 (n=26)	8	0.30	7 (26)
	1987	70	1.76 (n=38)	13	0.30	8 (20)
	1988	69	1.76 (n=38)	20	0.51	19 (49)
Atkinson Point	1984	63	1.90 (n=31)	37	1.21	24 (73)
	1985	44	1.89 (n=19)	21	0.81	19 (73)
	1986	36	1.79 (n=19)	14	0.67	11 (52)
	1987	65	1.74 (n=35)	32	0.84	21 (55)
	1988	77	1.87 (n=38)	46	1.10	33 (79)
Nuvorak Point[4]	1984	58	1.67 (n=24)	34	0.97	22 (63)
	1985	43	1.70 (n=20)	15	0.54	13 (46)
	1986	45	1.65 (n=26)	9	0.32	9 (32)
	1987	91	1.74 (n=47)	37	0.70	26 (49)
	1988	89	1.69 (n=52)	20	0.38	16 (30)
Husky Lakes[5]	1984	50	1.85 (n=27)	22	0.78	18 (64)
	1985	46	1.67 (n=15)	29	1.07	18 (67)
	1986	36	1.67 (n=18)	12	0.50	12 (50)
	1987	55	1.73 (n=30)	19	0.60	16 (50)
	1988	62	1.79 (n=33)	20	0.56	18 (50)
King Point[6]	1984	--	--	--	--	-- --
	1985	48	1.62 (n=14)	34	1.03	27 (82)
	1986	42	1.71 (n=21)	21	0.84	17 (68)
	1987	76	1.87 (n=38)	40	0.95	29 (69)
	1988	71	1.68 (n=38)	30	0.68	23 (52)

[1]Includes eggs of chicks from nesting territories discovered after hatch.
[2]Difference between years is significant at Toker, Nuvorak and Atkinson (X^2 tests, $p < 0.05$).
[3]Percentage of proven breeding pairs that were successful. Difference between years is significant at Toker, Nuvorak and King (X^2 tests, $p < 0.05$).
[4]In 1984, 10 km^2 of study plot not surveyed.
[5]In 1984, 4 km^2 of study plot not surveyed.
[6]In 1984, King Point study plot not surveyed.

Throughout the study period, breeding success was highest on average at King Point and Atkinson Point, and lowest at Nuvorak Point (Fig. 4; Table 5). The percentage successful pairs averaged 68% at King Point and 66% at Atkinson Point, compared to only 44% at Nuvorak Point. Similarly, the number of young fledged per active territory averaged 0.88 young/pair at King Point and 0.93 young/pair at Atkinson Point, but only 0.58 young/pair at Nuvorak Point.

3.1.2 Toker Point study plot

Four of the study plots were surveyed only three times each year, whereas the Toker Point study plot was surveyed every three to five days by foot throughout the breeding season from mid-June to the end of the first week in September, 1985 to 1988. Due to the frequency of visits, the breeding statistics for Toker Point study plot which are presented in Table 6 are more accurate than the similar data presented in Tables 4 and 5 which are based on only three visits a year. However, the more intensive surveys at Toker Point also had a greater influence on breeding success.

The number of Red-throated Loons that established a territory in the Toker Point study plot ranged from 45 to 49 pairs between 1985 and 1988 which was not a significant change from year to year (X^2 = 0.23, 3df, p=0.97) (Table 6). However, the breeding effort did differ between years (X^2 = 8.55, 3df, p=0.036), especially in 1986 when 25% fewer pairs attempted to nest relative to other years. Clutch size was similar from year to year with an average of 1.83 eggs laid. There

Table 6. Breeding statistics for the Red-throated Loon obtained by continually monitoring the Toker Point study plot throughout the breeding season.[1]

	1985	1986	1987	1988
Occupied territories	47	45	49	49
Active territories	42	32	43	44
% pairs that nested	89%	71%	88%	90%
Eggs[2]	92	66	97	86-97[4]
Average clutch size	1.87 (n=47)	1.80 (n=36)	1.81 (n=53)	1.83 (n=41)
Eggs hatched[2]	37	12	14	35-57
% eggs hatched	38%	17%	14%	55%
Young fledged[3]	23	8	9	14
% young fledged	62%	67%	64%	25-38%
% eggs fledged	25%	12%	9%	14-16%
Young fledged/breeding pair	0.55	0.25	0.21	0.32
Successful pairs	18	7	6	14
% successful pairs	43%	22%	14%	32%

[1]Based on both first and second clutches.
[2]Includes eggs of chicks from nesting territories discovered after hatch.
[3]Assumed 2 chicks at nest site T-5 in 1985 did not fledge (36 to 39 days old at freeze-up on 19 September); assumed chick at T-6 and chick at T-22 in 1988 did not fledge (38 and 36 days old respectively at freeze-up on 23 September).
[4]Includes 11 nests of unknown clutch size which we assumed had either 1 or 2 eggs.

were never more than two eggs per clutch. Hatching success varied between years (X^2=38.0, 3df, p <0.001), ranging from 55% in 1988 to only 14% in 1987. Survival of young until near fledging was fairly constant at 62% to 67% from 1985 to 1987, but dropped to 38% or lower in 1988. Overall, breeding success was low at Toker Point, ranging from 43% of the nesting pairs raising at least one young to near fledging in 1985 to only 14% successful pairs in 1987. Likewise, the average number of young fledged per breeding pair for the four years was only 0.33 young per pair.

From 26% to 40% of the loons that lost their eggs to predators laid a second clutch (Table 7). Although the clutch size was similar to that of the first nesting attempt (1.81 eggs compared to 1.84 eggs in first clutches), breeding success was low. The number of young fledged per breeding pair ranged from none in 1986 and 1988 to 0.38 young per pair in 1985.

3.2 Phenology

The following data on phenology were obtained during the ground surveys at Atkinson Point in 1984, and at Toker Point from 1985 to 1988.

3.2.1 Egg laying

Most years, egg laying at Toker Point began around 12 June and was completed by the first week in July with a mean date of egg laying between 21 and 25 June (replacement clutches not included) (Table 8). In 1986, however, there was nearly a two week delay in nest initiation, for egg laying did not begin until 26 June and the mean date of egg

Table 7. Replacement clutches laid by the Red-throated Loon at Toker Point study plot from 1985 to 1988.

	Year			
	1985	1986	1987	1988
No. of pairs that lost first clutch	23	23	40	20
No. of re-nests	8	6	11	8
% of loons with predated clutches that laid a second clutch	35%	26%	28%	40%
No. of eggs in second clutches[1]	15	11	18-19	13-15
Ave. size of second clutch	1.88 n=8	1.83 n=6	1.70 n=10	1.83 n=6
Eggs hatched (%)	7 (47%)	0	8 (42-44%)	10-14 (66-100%)
Young fledged (%)	3 (43%)	0	4 (50%)	0
Young fledged per breeding pair	0.38	0.00	0.36	0.00
% successful pairs	38%	0	27%	0
Range in dates when first clutches were lost	25 June-10 July n = 8	30 June-6 July n = 4	27 June-13 July n = 11	27 June-10 July n = 7
Mean initiation date of replacement clutch (range)	10 July (4-17 July) n = 4	17 July (16-18 July) n = 3	9 July (1-12 July) n = 3	16 July (7-23 July) n = 4
Mean no. of days between loss of first clutch and laying replacement clutch (range)[2]	10 days (8-13 days) n = 4	14 days (10-17 days) n = 2	9 days (6-11 days) n = 3	10 days n = 1

[1]Includes eggs of chicks from nesting territories not discovered until after hatch.
[2]Accuracy within 2 days.

Table 8. Comparative dates of egg laying for Red-throated Loons at Atkinson Point in 1984 and at nearby Toker Point from 1985 and to 1988.

Mean date first egg of clutch laid (range)[1]				
1984	1985	1986	1987	1988
22 June	21 June	4 July	25 June	21 June
(14 June - 2 July)	(10 June - 5 July)	(26 June - 12 July)	(17 June - 2 July)	(11 June - 10 July)
n = 20	n = 31	n = 22	n = 22	n = 38

[1]Replacement clutches not included. If date of lay was unknown, it was estimated by back-dating from time of hatch assuming the first egg was incubated 26 days.

laying was not until 4 July. The difference between years in the timing of nest initiation was significant (using five day intervals, $X^2 = 77.2$, 21df, $p < 0.005$), with observations from 1986 alone contributing 50% to the value of the X^2. The two eggs within a clutch were usually laid two days apart, but sometimes three days apart (2 days apart for 3 pairs; 3 days apart for 1 pair; 2 or more days apart for 19 pairs; 3 or more days apart for 3 pairs).

Replacement clutches were laid an average of 10 days after loosing the first clutch (range: 6 to 17 days, n=10) (Table 7). In all four years at Toker Point, no replacement clutches were laid after 23 July. Nor were any replacement clutches laid for nests where the eggs were lost after 13 July or where chicks were lost.

3.2.2 Incubation

The first egg laid in a clutch was incubated an average of 26 days (range: 25 to 27 days, n=7), whereas the second egg was incubated 25 days (range: 24 to 25 days, n=6).

3.2.3 Hatch

The eggs within a clutch hatched 1 day apart in 4 clutches, 2 days apart in 2 clutches and 3 days apart in 1 clutch.

3.2.4 Fledging

Most of the Red-throated Loon chicks at Toker Point fledged between late August and mid-September (Fig. 5). However, in 1986 the

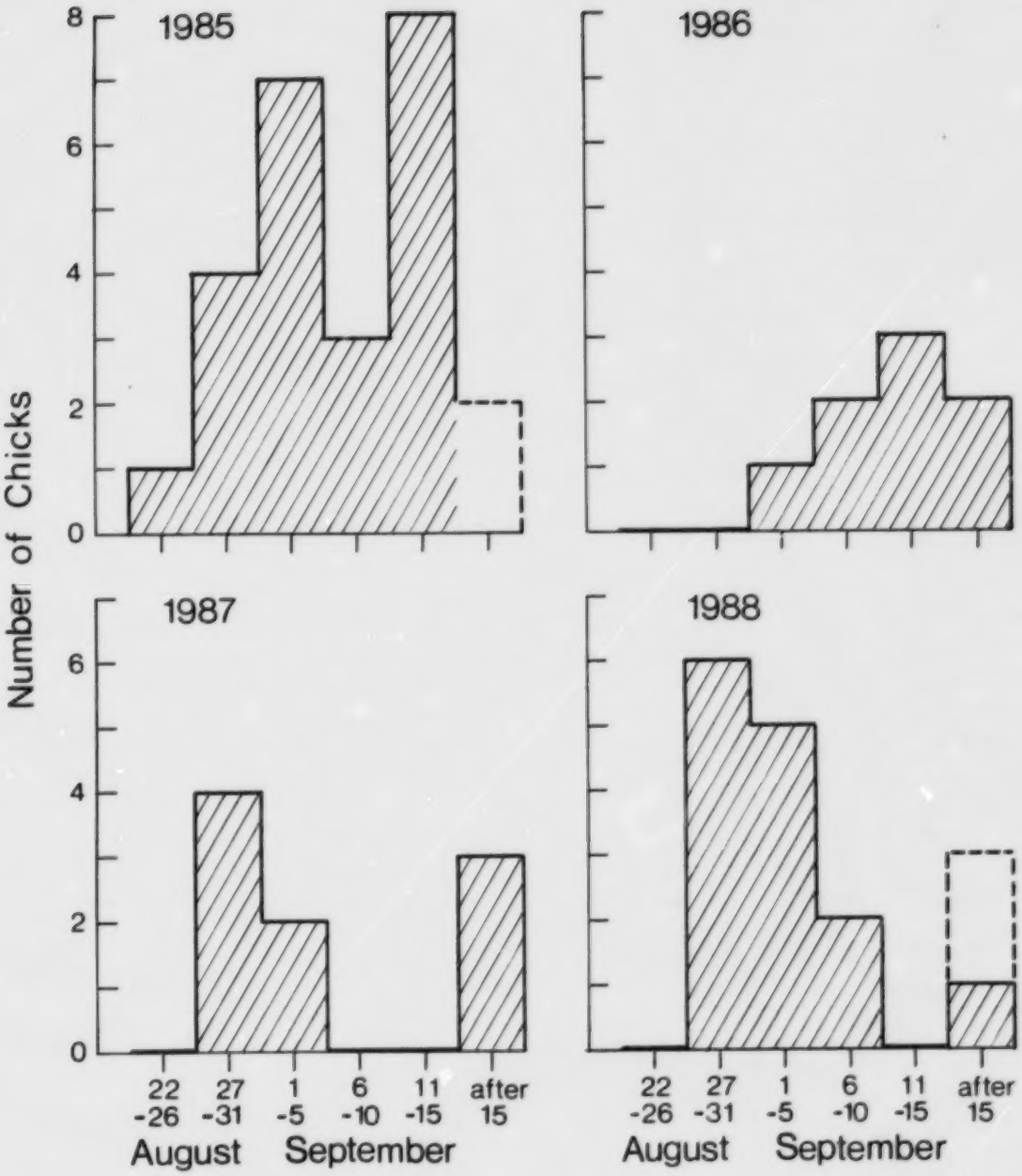

Figure 5. Fledging dates of Red-throated Loon chicks at the Toker Point study plot from 1985 to 1988 (dotted line indicates ponds froze before chicks were 40 days old, hence they may not have survived).

mean date of fledging occurred over a week later than average (13 September in 1986, compared to 4 September in 1985 and 1988 and 31 August in 1987 - chicks from replacement clutches not included).

The number of days required for chicks to fledge averaged 47 days and ranged from 43 to 52 days (n=10). The approximate number of days until fledging was recorded for an additional 30 chicks. Based on the data for all 40 chicks, it took an average of 46 days for them to fledge.

3.3 Aging eggs

3.3.1 By weight and size

From 1985 to 1987, a total of 133 eggs at 77 nest sites at Toker Point were weighed every three to six days, and measured for their length and width. The decrease in the density of the eggs as they aged was then calculated. Whenever either the exact date of hatch or date of egg laying was unknown, we assumed that the eggs were laid two days apart and hatched one day apart (Davis 1972; Bundy 1976), and that the incubation period was 26 days for the first egg and 25 days for the second egg (Section 3.2.2). At sixteen nest sites where neither date of lay nor the date of hatch was known, the age of the egg was determined by floatation. Addled eggs were eliminated from the analysis.

The density of the eggs was regressed on age and the resulting linear equation was inverted to express days until hatch as a function of density:

$\widehat{\text{days}}$ until hatch = -133.297 + 144.663 (density)

$R^2 = 0.753$

The estimated variance of days was:

$$S^2(\widehat{days}) = 11.886 \left[1 + \frac{1}{546} + \frac{(\text{density} - 1.0359)^2}{0.9467}\right]$$

and the 95% Confidence Interval for $\widehat{days}$ was:

$$\widehat{days} \pm t_{1-\frac{\alpha}{2},n-2} \cdot \sqrt{S^2(\widehat{days})}$$

$t_{.975,544} = 1.964$

Thus, if the egg weighed 69.0 gm, was 7.272 cm long and 4.204 cm wide:

density = 1.059 gm/cm^3

days until hatch = 19.9

S^2(days until hatch) = 11.9

95% Confidence Interval = ±6.78

Therefore, the egg would hatch in 20 ± 7 days.

3.3.2. By egg floatation

Eggs at 70 nests in the Toker Point study area were floated in a container of lukewarm water every 3 to 6 days in 1985, 1986 and 1987. The changes in the way the eggs floated throughout incubation were summarized, then depicted graphically (Table 9; Fig. 6). Addled eggs, and eggs without either a known date of lay or hatch were excluded from the summary.

During the first five days of incubation, the eggs rested on the bottom of the container of water at an angle of 15° or less (Table 9;

Table 9. Changes in egg floatation with incubation for the Red-throated Loon at the Toker Point study plot.

Days until hatch	Description	Percentage of observations that fit description	Bouoyancy		
			On bottom	Neutral	Floating
22-26	On bottom at 0° to 15°	97% (n = 98)	100%	0%	0%
18-21	On bottom at 16° to 40°	80% (n = 79)	100%	0%	0%
14-17	On bottom at 41° to 75°	57% (n = 68)	100%	0%	0%
10-13	On bottom at 76° to 90°	67% (n = 40)	78%	5%	17%
9	Transition between floating and resting on bottom; angle of egg 85° to 90°.	94% (n = 18)	39%	28%	33%
6-8	Floating at 85° to 90° with $\leq$0.5 cm above surface and <1.6 cm egg width at surface.	68% (n = 19)	5%	16%	79%
3-5	Floating at 85° to 90° with >0.5 cm above surface, and $\geq$1.6 cm egg width at surface	88% (n = 32)	0%		100%
1-2	Floating at <85° with >0.7 cm above surface and $\geq$1.8 cm egg width at surface	75% (n = 8)	0%		100%

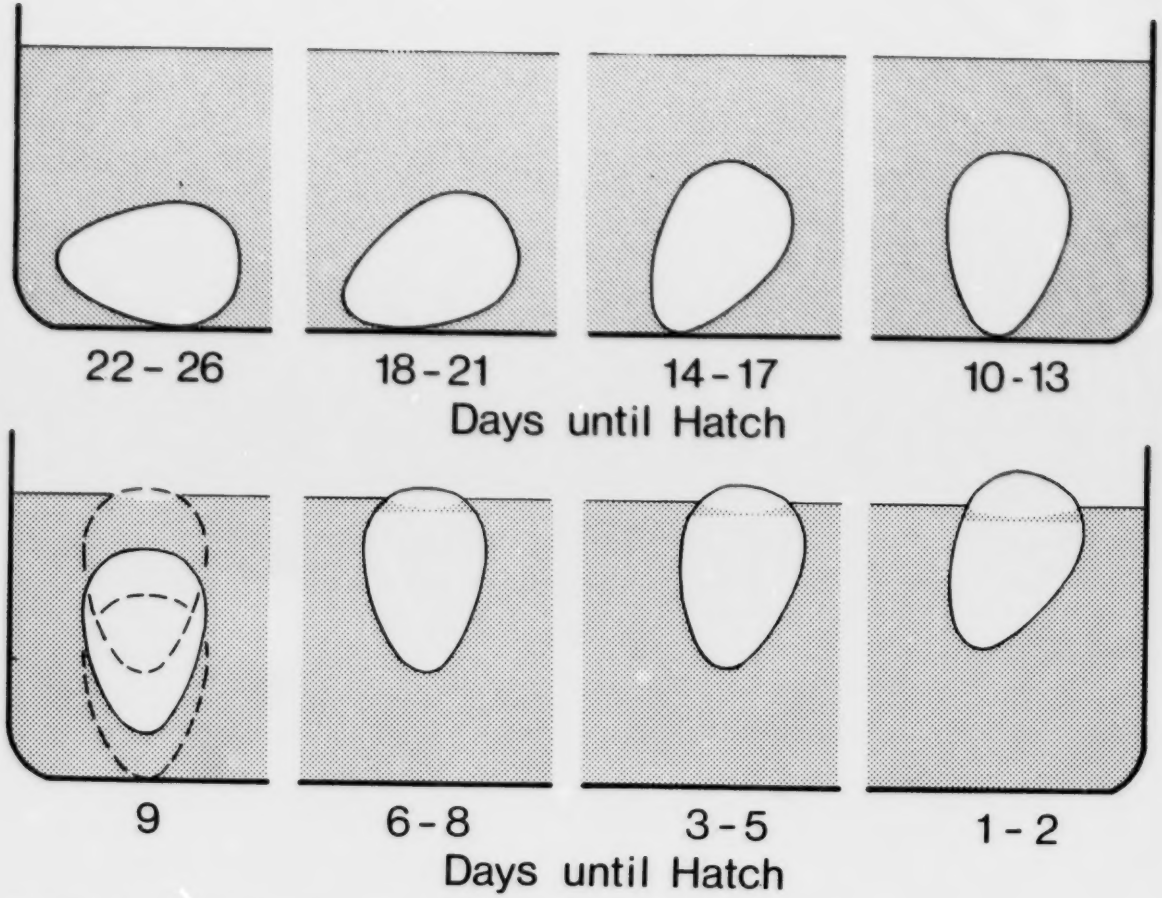

Figure 6. Changes in egg floatation with incubation for the Red-throated Loon at the Toker Point study plot.

Fig. 6). Over the next eight days, the large end of the egg gradually lifted until by two weeks most of the eggs were standing upright on the bottom of the container. The eggs floated to the surface 7 to 13 days before hatch, with the majority rising 8 to 10 days before hatch. In the last five days, the eggs emerged out of the water nearly a centimetre and tilted to an angle of about 80^{o}.

3.4 Aging chicks

The size, shape and plumage of 30 loon chicks of a known age at Toker Point were recorded about every five days until the chicks fledged. Using the information on size, an equation to estimate the age of a chick based on its size was developed following a technique described by Johnson et al. (1975). First, we determined the growth pattern of the chicks as a function of age (time) using the following model:

$$S(t) = (A^{1-m} + \beta e^{-kt})^{\frac{1}{1-m}}$$

Where S(t) = size of chick at time t

A = asymptotic growth limit

β = a parameter related to time origin (i.e. size at hatch)

m = a shape parameter

t = time

K = growth rate

Using initial values of m = 1.5, β = 1.0 and k = 1.5, and setting A = 100%, this model was fit to 210 size-age data points by Simplex and Quasi-Newton minimization methods (Wilkinson 1988). Both methods converged to:

Estimate	Asymptotic standard error	95% confidence internal
$m = 2.222$	0.314	1.603, 2.841
$\hat{\beta} = 0.0612$	0.048	-0.035, 0.155
$K = 0.1558$	0.016	0.125, 0.187

The resultant growth curve is depicted in Fig. 7.

So that age could be estimated from the size of the chick during the aerial surveys for chicks near fledging, the above model was inverted:

$$\text{Age} = \frac{\ln\left\{[(\text{size})^{1-m} - 100^{1-m}]/\hat{\beta}\right\}}{-K}$$

It was not possible to determine the true estimates of the standard error due to the nonlinear nature of the growth curve. However, a lower bound for the variance was calculated by grouping the observed chick sizes into classes, then computing the variance of the ages in each size class (Johnson et al. 1975) (Table 10). Thus, for example, the minimum standard deviation of an age calculated for a chick 31 to 40% adult size would be 3.885 days, and the lower bound of variance for 95% confidence limits would be ± 2.348 using

$$\pm\, t_{1-\frac{\alpha}{2},\, n-1} \cdot \frac{s}{\sqrt{n}}$$

The precision of the equation that estimates age was also assessed, primarily to determine the range of ages for which the equation was useful.

$$\text{Var (age)} = \left[\frac{d\ \text{age}}{d\ \text{size}}(\text{size})\right]^2 \text{Var (size)}$$

Thus the derivative,

$$\frac{d\ \text{age}}{d\ \text{size}} = (m-1)\ (\beta k)^{-1}\ (\text{size})^{-m}\ e^{k-\text{age}}$$

governs the variance of age.

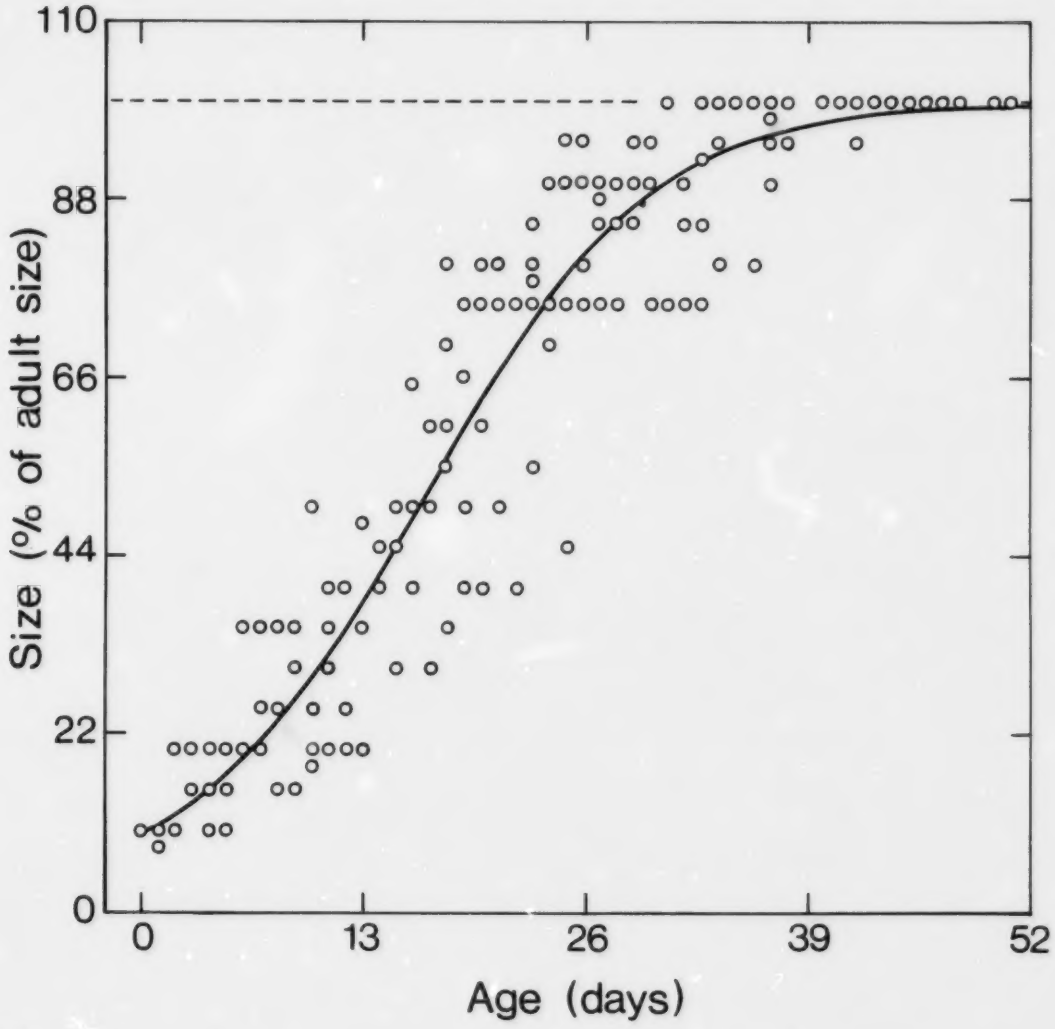

Figure 7. Rate of growth of Red-throated Loon chicks at the Toker Point study plot.

Table 10. Variance of the predicted age of the Red-throated Loon chicks at Toker Point study plot.

Percent of adult body size	Size class	Sample size	Age of chick (days)		
			Mean	Standard deviation	Standard error
0-10	1	1			
11-20	2	31	2.935	2.792	0.501
21-30	3	19	7.737	3.177	0.729
31-40	4	13	11.385	3.885	1.077
41-50	5	14	15.571	4.327	1.157
51-60	6	12	17.083	3.204	0.925
61-70	7	6	18.333	1.633	0.667
71-80	8	24	24.375	4.528	0.924
81-100	9	90	35.267	7.849	0.827

The resultant graph of the derivative $\frac{d\ age}{d\ size}$ (Fig. 8) illustrates that age can be predicted from size with reasonable confidence up to about 37 days of age. After this point, the variance becomes to large.

An age classification system for chicks was developed using the growth curve and chick descriptions (Table 11). For the first nine days, the chicks were downy and ball-shaped. During the second week, the body elongated, and the head and neck became lighter in colour. By two weeks the chicks were about 40% of adult body size, and by three weeks they were two-thirds the size of an adult (Fig. 7). During the third and fourth week, feathers developed on the back, sides and the rump. By the end of the fifth week, the chick appeared nearly full grown (over 90% of adult body size), only small clumps of down remained, and a pale cheek patch became prominent. By 42 days, most chicks had no visible down, and had acquired an adult shape.

3.5 Mortality of eggs and chicks

Most years at Toker Point, the mortality rate was much higher for eggs than chicks (Fig. 9). For example in 1987, the average weekly mortality rate for eggs was 38% compared to 10% for chicks up to 21 days old. The exception was 1988 when the highest mortality occurred with freshly hatched chicks less than one week old (38% mortality). That year, the weekly mortality for eggs averaged only 12% compared to 26% for chicks up to 21 days old.

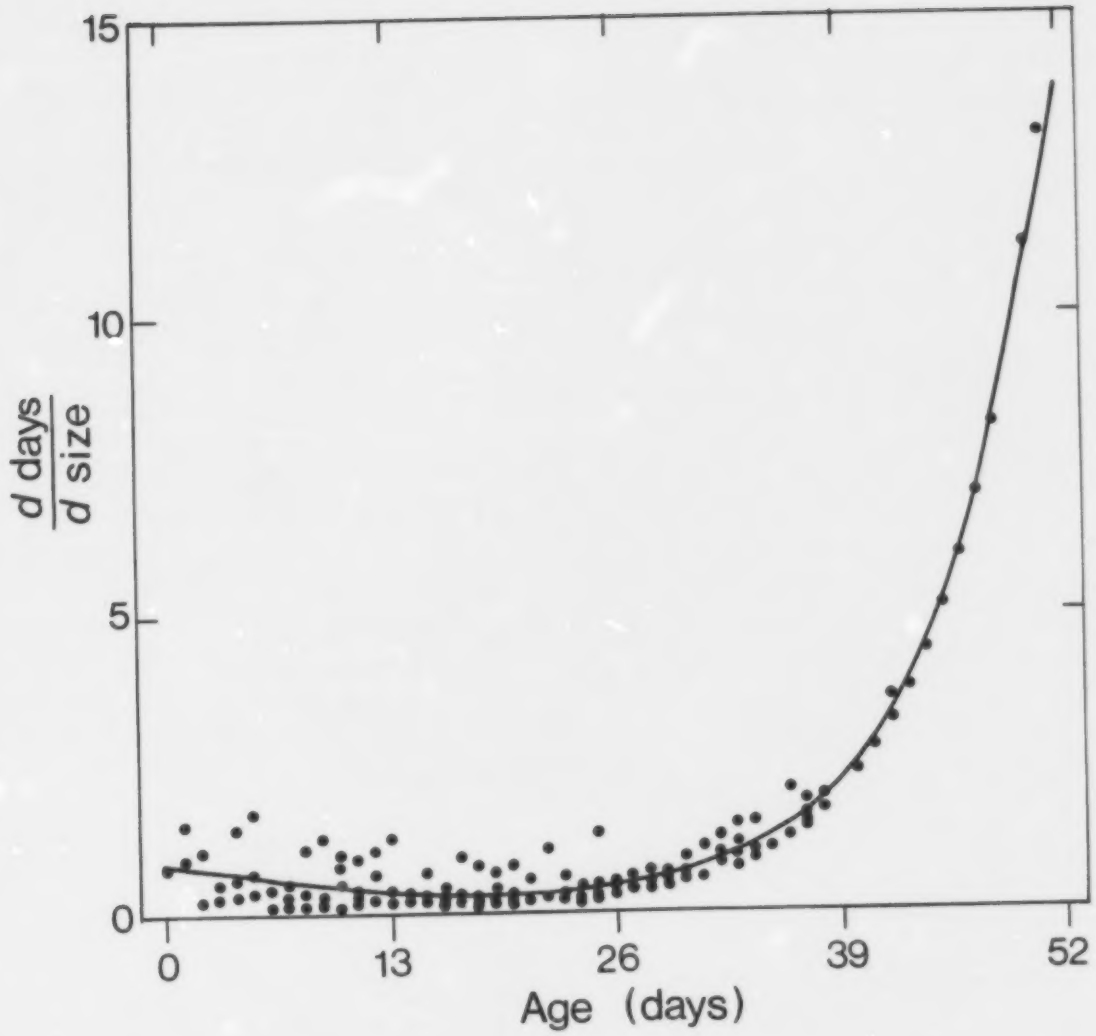

Figure 8. Precision of the equation for estimating the age of a Red-throated Loon chick from its size.

Table 11. Age classification of Red-throated Loon chicks according to plumage development, shape and size, based on chick descriptions at the Toker Point study plot.

	Class	Age in days	Description of plumage and shape	Size (% of adult size)
1	Downy	0-9	Downy with no feathers visible; ball-shaped; neck and tail not prominent.	10-25
2A	First Feathers	10-16	Head and neck appear lighter in colour and fuzzy*; back, sides and rump still dark and downy; body and neck elongated.	26-50
2B	Partly to Mostly Feathered	17-31	Head and neck light grey; back, sides and rump mixture of feathers and down; body elongated, but small head and short neck.	51-90
2C	Last Down	32-40	Clumps of down remain on sides, rump and back; underbody light; white cheek patches.	91-100
3	Fully Feathered	41-52	Completely feathered; adult-like; white cheek patches, white breast, speckled back; fledges during this period.	100

*A second paler down plumage is acquired (Palmer 1962; Bundy 1976).

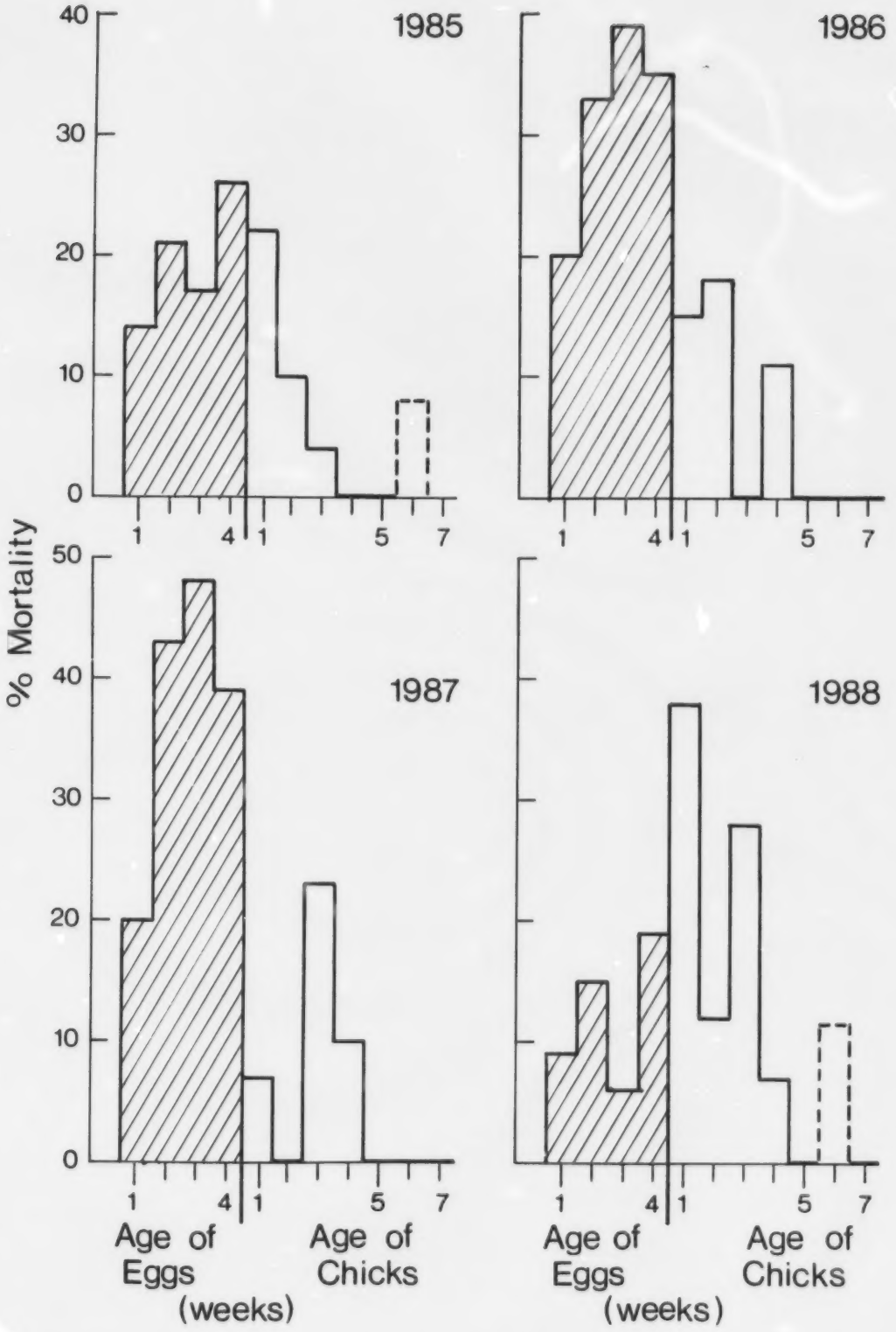

Figure 9. Red-throated Loon egg and chick mortality rates for Toker Point study plot (% mortality = no. lost during week/no. available at begining of week (x 100%), addled or infertile eggs and eggs of unknown age were excluded from analysis; dotted line indicates death of chicks assumed since ponds froze when they were less than 40 days old).

Few chicks died after three weeks of age. Of the 50 chicks lost after hatch during the four years of study, all but 7 died in the first three weeks after hatch. We are assuming that 4 of these 7 chicks died at 5 to 6 weeks old because their ponds froze over prior to the age when they normally fledge. The other three disappeared in their fourth week.

3.6 Abundance of predators

Throughout June and July from 1985 and 1988, a daily record was kept of the number of predators of loon eggs and chicks seen in the Toker Point study plot (Table 12; Appendix B). The most common predator species were the Glaucous Gull, Parasitic Jaeger, Common Raven, Sandhill Crane and arctic fox. Fox dens and nesting pairs of avian predators found within the study area were plotted on a map each year (Appendix C), and total numbers of nesting pairs with hunting territories at least partly within the study area were tabulated (Table 13). A pair of avian predators was recorded as nesting if either a nest was found or if the pair was seen repeatedly in the same location during the nesting period.

The number of arctic foxes in the study area was low in 1985, rose significantly to a peak in 1987, then dropped again in 1988 (Quade Test, $T = 14.74$, $K_1 = 3$, $K_2 = 24$, $p < 0.05$) (Table 12; Appendix B). None of the other major predator species differed significantly in numbers between years (Quade Tests, $p > 0.05$), except Glaucous Gull chicks which were three times more abundant in 1988 than in 1986 ($X^2 = 15.8$, 3df, $p < 0.05$) (Table 13).

Table 12. Comparison of the number of predators of loon eggs and chicks seen each year at the Toker Point study plot between 17 June and 9 August.

Species	Mean daily count[1]			
	1985	1986	1987	1988
Sandhill Crane	5.5	6.1	5.0	6.3
Parasitic Jaeger	4.3	2.6	3.8	3.5
Glaucous Gull	30.1	30.5	28.1	22.5
Common Raven	1.2	0.7	0.9	0.5
Arctic Fox	0.0	0.3	0.9	0.1

[1]The number of arctic foxes differed significantly between all years except 1985 and 1988: Quade Test, $T = 14.74$, $K_1 = 3$, $K_2 = 24$, $p < 0.05$. There were no significant differences between years for the other species at $p > 0.05$.
The daily count was initially calculated from observations recorded over a 6-day interval, since it took three to six days to survey the entire study area (Appendix B).

Table 13. Summary of predatory bird species nesting in the Toker Point study plot each year from 1985 and 1988.

Species	Number of pairs (number of young)[1]			
	1985	1986	1987	1988
Glaucous Gull[2]	38 (30)	40 (14)	32 (22)	36 (42)
Sabine's Gull	0	0	1	0
Parasitic Jaeger	4 (1)	6 (0)	6 (2)	3 (3)
Long-tailed Jaeger	0	0	0	1
Sandhill Crane	3 (3)	12 (0)	8 (0)	10 (6)
Common Raven	0	2	1	1
Northern Harrier	1	0	0	1
Rough-legged Hawk	1	3 (5)	3 (4)	4 (7)

[1]Nesting based on behavior and repeated sightings in same area. Refer to Appendix C for location of nesting territories.
[2]Difference in the number of Glaucous Gull chicks between years is significant ($X^2 = 15.8$, 3df, $p < 0.05$).

3.7 Abundance of prey other than loon eggs and chicks

Nests of all bird species found within the Toker Point study plot were recorded each year. The number of nests found varied from year to year (X^2 test, 3df, $p < 0.05$), with the lowest number occurring in 1986 (Table 14; Appendix D). Likewise, fewer eggs and chicks of all species were found in 1986. Like the Red-throated Loon, although a relatively large number of waterfowl nested in 1987, few young were produced. Only 33 young-of-the-year waterfowl were seen in 1987, compared to 226 young in 1985 and 236 young in 1988.

The number of arctic ground squirrels seen was recorded daily from 17 June to 9 August (Table 15). The average number seen per day was 1.19, 0.65, 2.01 and 1.84 in 1985, 1986, 1987 and 1988 respectively. This difference between years was not significant (Quade Test, T=1, K_1 = 3, K_2 = 18, $p > 0.05$).

Small mammals were live-trapped for 10 days between 5 and 15 July in 1987 and again in 1988. All mammals captured were red-backed voles (Clethrionomys rutilus), except one caught in 1988 which was a meadow vole (Microtus pennsylvanicus). Voles were significantly more abundant in 1988 (Sign Test, T=14, $p < 0.05$). Excluding recaptured voles, 6.6 voles/100 trap-nights were caught in 1988, compared to only 4.0 voles/trap-night in 1987 (recaptured voles not included) (Appendix E).

3.8 Abundance of prey for loons and chick feeding frequency

The coastal waters off the Toker Point study plot were surveyed from shore 6 times in 1985, 19 times in 1986 and 4 times in 1987 to

Table 14. Number of nests, eggs and young of species other than the Red-throated Loon found at Toker Point study plot from 1985 to 1988.

	Number of nests[1]				Number of eggs and chicks[2]			
	1985	1986	1987	1988	1985	1986	1987	1988
Waterfowl	21	11	33	20	301	111	126	318
Shorebirds	9	11	20	14	51	43	80	61
Passerines	18	16	35	45	80	69	159	197
All species	97	76	157	151	574	321	460	693

[1]Differences between years are significant except for shorebirds (X^2 tests, 3 df, $p < 0.05$).
[2]All differences between years are significant (X^2 tests, 3 df, $p < 0.05$).

Table 15. Number of arctic ground squirrels seen daily at Toker Point from 1985 to 1988.

	Mean number of arctic ground squirrels seen per day by 6-day intervals[1]								
Year	June 17-22	June 23-28	June 29 -July 4	July 5-10	July 11-16	July 17-22	July 23-28	July 29 -Aug. 3	Aug. 4-9
1985	0.83	0.00	0.17	0.75	3.33	0.40	3.17	1.75	0.33
1986	0.50	0.17	0.33	0.00	1.17	0.17	0.83	1.67	1.00
1987	0.33	0.17	0.17	1.50	0.17	2.00	4.00	5.25	4.50
1988	2.83	1.75	1.50	2.00	2.00	1.50	ND	ND	1.33

ND-no data
[1]No significant difference between years (Quade Test, T=1.70, K_1=3, K_2=18, p>0.05).

determine where the Red-throated Loons were feeding (Fig. 2). Loons were seen throughout the three bays, but most were within 200 m of shore (Fig. 10). However, on calm days they were seen feeding farther offshore, including outside the bays. On windy days they tended to use a leeward shore, although overall, they were most frequently seen feeding along the southeast shore of the two bays nearest Toker Point.

In 1985 and 1987, the activities of Red-throated Loons on freshwater lakes were monitored for a total of 23 hours to see if they were getting fish for their young from fresh as well as salt water. Although there were as many as eight loons at a time on the lakes, we saw a loon with a fish in its bill only once.

About once a week from mid-July to early September from 1986 to 1988, fish were caught with a beach seine to determine the relative abundance of prey for the Red-throated Loons (Fig. 2; Table 16; Appendix F). The fish caught varied in size from 2 to 47 cm, but only fish from 5 to 20 cm have been reported here since that is the size Red-throated Loons normally feed their chicks (Norberg and Norberg 1977; Reimchen and Douglas 1984). Coregonids accounted for about 90% of the catch (5 to 20 cm long) over the three years: 55% of the fish were least ciscos, 20% were arctic ciscos, 10% were broad whitefish, 1% were lake whitefish and 4% were unidentified coregonids. The remaining 10% were mostly fourhorn sculpins and rainbow smelt, although a few pacific herring, northern pike, ninespine stickleback and arctic flounder were also captured. Catch per unit effort (number of fish per 100 m of shoreline seined with a 10 m long net) was significantly higher in 1988

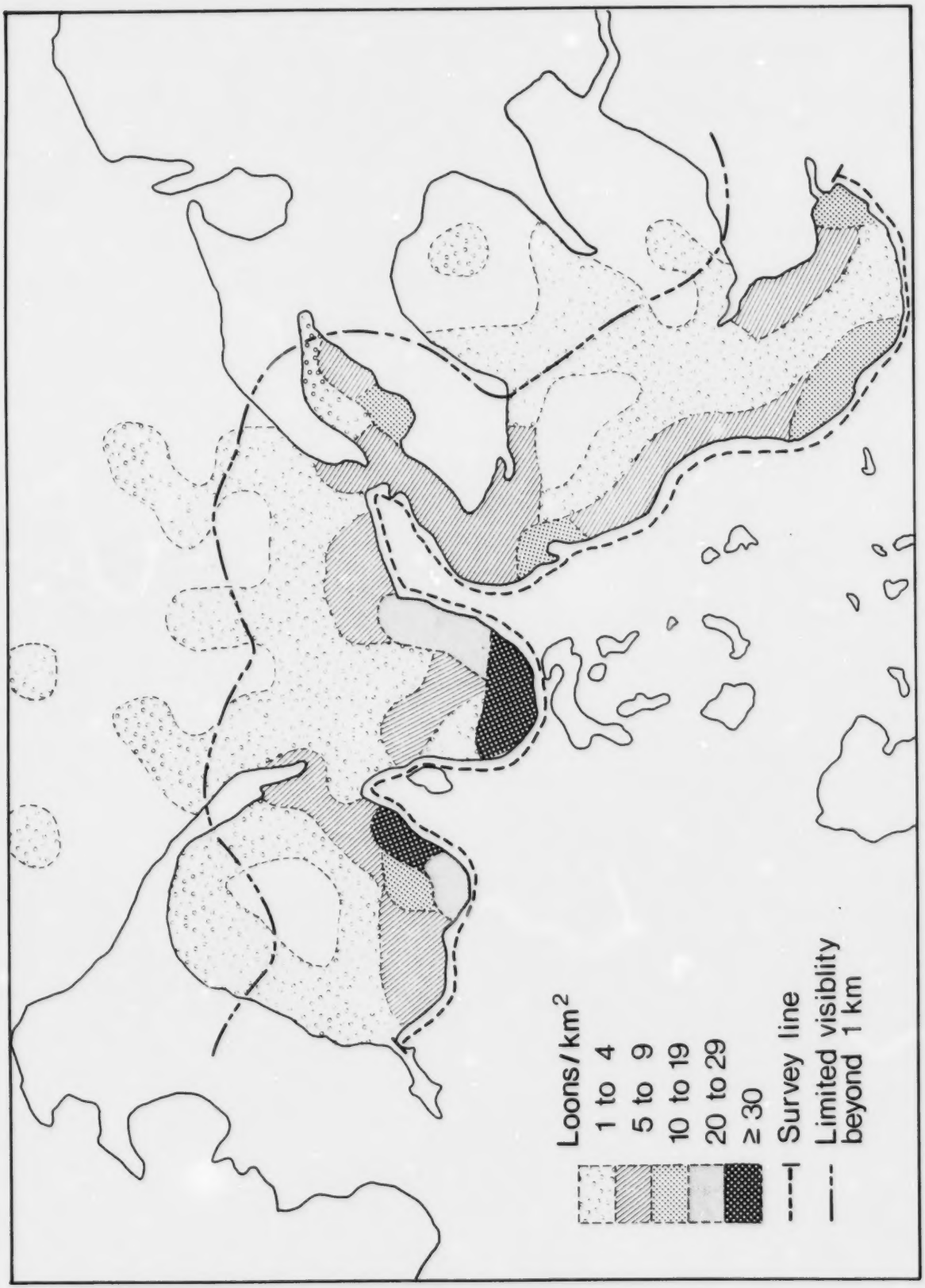

Figure 10. Feeding areas of the Red-throated Loon at the Toker Point study plot.

Table 16. Comparison of the abundance of food for Red-throated Loons (fish with a fork length of 5 to 20 cm) at Toker Point from 1986 to 1988.

	Catch per unit effort (SD)[1]	
Year	All species	Species loons eat[2]
1986	60.8 (83.4)	57.8 (82.5)
1987	31.9 (53.4)	30.6 (54.1)
1988	40.9 (21.9)	34.4 (22.8)

[1]Number of fish caught per 100 m of shoreline seined with a 10 m long net.

[2]All species except sticklebacks, sculpins and flounders. Significant difference between 1987 and 1988 (Mann-Whitney U-test, U=374, p=0.00). Note, 1986 not statistically comparable, because seined at different sites.

than in 1987 (Mann-Whitney U-test, U = 374, p = 0.00). The catch in 1986 was even higher; however, these data were not statistically comparable since seining that year was conducted at several different sites rather than the same site as was done in 1987 and 1988 (Fig. 2).

Red-throated Loon pairs with chicks were observed to determine the frequency of times the adults fed their young at Toker Point. Two-hour watches were conducted every 4 hours for 24 hour periods about twice a week from late July to the end of the first week in September. The number of hours of observation each year is presented in Table 17 and the locations of the bird-blinds are shown in Figure 2. The adult loons brought an average of 8.3 fish to each chick per day, based on all four years of data (Table 17). There was no relationship between the age of the chick and the feeding rate (R^2 = 0.004, F = 1.32, df = 1,72, p = 0.26). Nor was there a significant difference in the number of fish brought to the chicks from one year to the next (Kruskal-Wallis Test, p>0.05). An average of 4% of the fish brought to the chicks were not eaten, either because the fish was too big or because the chick appeared not hungry. At one site in 1988, the chick refused 14% of the fish and died at about three weeks old.

3.9 Weather

At Toker Point, a daily record of the temperature, wind speed and direction, precipitation and cloud cover was kept from mid-June to the end of the first week in September from 1985 to 1988. In 1984, the weather was recorded at Atkinson Point from 2 to 20 June and from 7 to

Table 17. Number of fish that Red-throated Loons brought to their chicks each day at the Toker Point study plot.

Year	Nest site	Number of chicks	Number of fish per chick per day[1]	Percent of fish not eaten	Number of hours of observations
1985	T-35	2	9.8	5%	92
	T-36	1	9.8	8%	90
	T-72	1	10.1	4%	53
	Average		9.9		
1986	T-43	1	7.7	0%	123
1987	T-17	1	7.2	4%	81
	T-22B	1	9.8	0%	14
	Photoblind	2	5.5	4%	28
	Average		7.5		
1988	T-7B	1	7.4	14%	66
	T-9	1	8.0	2%	128
	T-11	1	8.5	0%	32
	Average		8.0		

[1]No significant difference between years in the number of fish brought to the chicks each day (Kruskal-Wallis Tests, $p > 0.05$). Also, no significant relationship between age and feeding rate ($R^2 = 0.004$, $F = 1.32$, $df = 1,72$, $p=0.255$).

31 July. In addition, weather records for Tuktoyaktuk from 1984 to 1988 were obtained from Atmospheric Environment Service (Appendix G). The following is a brief summary of the storms encountered each year.

In 1984, snow showers occurred at Atkinson Point from 15 to 18 July with winds from 50 to 60 kph on the later two days. The temperature remained above zero, however, so that snow did not accumulate on the ground. Another snow storm occurred on 26 August which was again accompanied by strong winds (60 kph). The storm lasted less than 24 hours, but left 8 to 10 cm of snow at Toker Point and several centimetres more at Atkinson Point. About 10% of the ponds at Atkinson Point and Toker Point that had Red-throated Loon chicks were completely frozen for at least two days following the storm.

In 1985, several snow storms occurred in July, but the mean temperature remained above freezing: snow on 5 and 6 July with 40 kph winds, on 17 July with 30 kph winds and on 19 July with 50 kph winds. From 15 to 18 September, there was a severe storm with snow and winds up to 70 kph. Of the ten ponds that had had Red-throated Loon chicks on 10 September at Atkinson Point and Toker Point, four had over 90% ice cover on 17 September.

In 1986, the only major storm during the breeding season at Toker Point occurred on 22 to 24 August. The wind speed reached 40 kph and about 2 cm of snow accumulated on the ground. However, the snow melted within 24 hours and the small ponds remained open.

Similarily, in 1987 there was only one storm which occurred from 28 to 31 August. Winds gusted to 55 kph, accompanied by both rain and

snow showers. However, it remained warm enough so that the snow did not accumulate on the ground.

In 1988, a storm with high winds (50 kph gusting to 70 kph), rain and snow showers occurred from 1 to 4 August. The snow did not accumulate on the ground, but unusually high tides due to the strong northwest winds resulted in flooding of the coastal lowlands all along the northwest shore of the Tuktoyaktuk Peninsula. Two ponds with Red-throated Loon nests at Toker Point were flooded during this storm and one at Atkinson Point, as well as approximately 20% of the Nuvorak Point study plot.

3.10 Timing of break-up and freeze-up

The timing of spring thaw varied from year to year, with early thaws occurring in 1984, 1985 and 1988 when temperatures were above normal, and late thaws occurring in 1986 and 1987 (Table 18; Fig. 11; Appendices G and H). Thirty thawing degree-days had been reached by late May or early June in the years of early thaw, but not until 18 June in 1986 and 9 June in 1987 (Table 18; Fig. 11). Consequently the shallow ponds used by the Red-throated Loon for nesting opened in early June most years, but not until 18 June in 1986. Also, the coastal waters where the loons feed became available 1 to 2 weeks later in 1986 and 1987 than in the other years.

The ponds used by the Red-throated Loon for brood-rearing froze on 28 September in 1984, 19 September in 1985, 24 September in 1986, 26 September in 1987 and 23 September in 1988 (former two dates based on

Table 18. Timing of spring break-up at Atkinson Point in 1984 and at Toker Point from 1985 to 1988.

Year	Mean daily temperature goes above 0°C for >2 days[1]	Reach 30 thawing degree-days[1]	Snow cover <5%	Marshes open	Shallow ponds open	Deep ponds open	Lakes (>0.25 Km^2) open	Coastal lead of >100 m
1984	31 May	3 June	6 June	5 June	6 June			14 June
1985	22 May	31 May	1st week of June	1st week of June	1st week of June	21 June	3 July	20 June
1986	6 June	18 June	16 June	16 June	15-18 June	25-27 June	13 July	1 July
1987	1 June	9 June	7 June	7 June	8 June	23-25 June	30 June	29 June
1988	25 May	4 June	late April	25 May	29 May	20 June	24 June	22 June

[1]From Atmospheric Environment Service

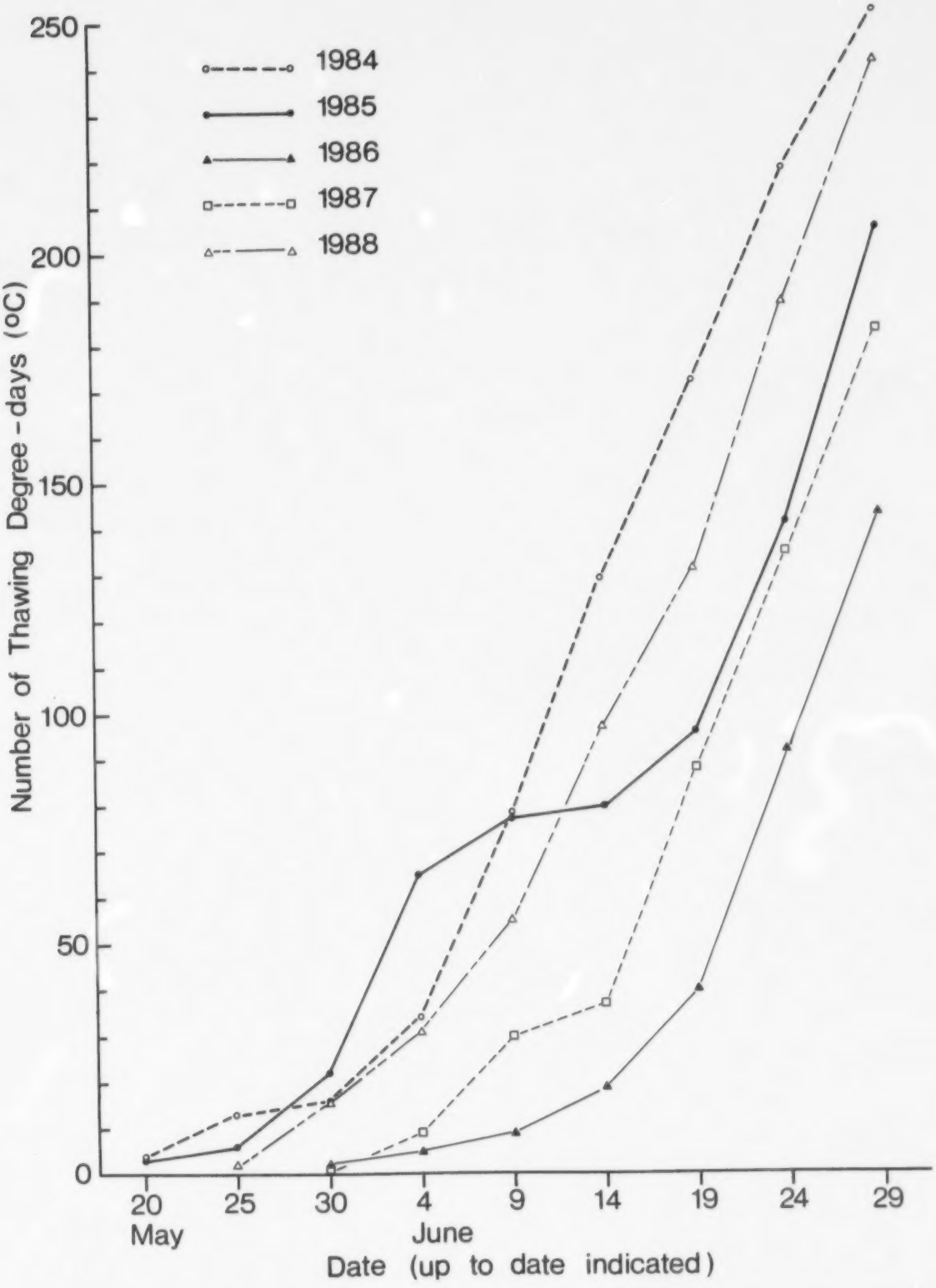

Figure 11. Cummulative number of thawing degree-days at Tuktoyaktuk airport (data provided by Atmospheric Environment Service).

Atmospheric Environment Service weather records for Tuktoyaktuk; the latter dates were provided by Ian Ross, Paul Voudrach and Louis Marion, Wildlife Enforcement Officers, Tuktoyaktuk, pers. comm.). These dates for freeze-up were likely a few days later than is typical, since temperatures in September were above normal in all five years (Appendix G).

3.11 Water-levels

Water-levels were measured in three wetlands at Toker Point in mid-July (1985 and 1988 only) and mid-August (1985 to 1988). Soil moisture and percent cover with standing water were recorded along transects in two of the wetlands, while the percent cover with water of a cluster of seven shallow ponds was recorded in the third wetland.

Water-levels in the wetlands at Toker Point were highest in 1986, following a winter of much higher than normal precipitation (73 mm more precipitation than normal at Tuktoyaktuk according to Atmospheric Environment Service (Appendix G)). Although water-levels were high that year, no nests were flooded, since rainfall in June and July was below normal.

The other three years had noticeably lower water-levels. In 1985 and 1988, the two driest years, several nests originally built in water became stranded on land several metres from the pond's edge by mid-July. In all four years, the shallowest nesting ponds at Toker Point were partly dry by late July.

Ponds photographed in early July showed that water-levels at Husky Lakes, Atkinson Point and Nuvorak Point were also highest in 1986, and lowest in 1985 and 1988. Changes in water-levels at King Point could not be detected using photographs, because none of the ponds had exposed mudflats at lower water-levels.

3.12 Reference specimens collected

From 1986 to 1988, the following specimens were collected from the Beaufort Sea region, frozen and stored in the tissue bank at the National Wildlife Research Centre in Ottawa to be used as references for environmental contaminants: 9 adult Red-throated Loons collected shortly after arrival on the nesting ponds in mid-June; 10 eggs from separate clutches collected in the early stages of incubation (all <7 days old) in late June and early July; 6 young-of-the-year Red-throated Loons from different broods collected in late August (five were live birds 4 to 6 weeks old and one was a dead bird about 18 days old); and 52 fish (fork length from 55 to 219 mm) collected in the middle bay north of the Toker Point study plot. See Appendix I for the exact dates and locations of the collections.

Pooled samples of the eggs collected in 1986 and 1987, as well as the livers of four adult Red-throated Loons collected in 1987 were analyzed for organochlorine residues by the National Wildlife Research Centre. Levels of all substances were low indicating very little contamination (Appendix J).

3.13 Nesting territories

From 1985 to 1988, Red-throated Loons at the Toker Point study plot occupied a total of 61 different nesting territories (includes both occupied and active territories). The location of these territories is shown in Figure 12. Nearly two-thirds of the territories consisted of only 1 pond, 30% had 2 ponds and 6% had 3 or more ponds. In several cases, the nest platform changed location to a different pond within the territory, either from one year to the next or after the first clutch was lost. These changes have been indicated by arrows in Figure 12.

There was a strong tendency for the Red-throated Loons to use the same territories each year (Fig. 12). Over half of the territories at Toker Point (57%, n=61) were occupied in all four years of the study, while only 20% were used just one year.

Neither hatching success nor fledging success affected whether the nesting territory was reoccupied the following year (X^2 tests, 1df, $p>0.05$). Ninety-two percent of the territories where at least one egg had hatched were reoccupied the following year (n=39), compared to a 90% reoccupancy following none hatching (n=78). Similarly, there was 94% reoccupancy of territories where young had fledged (n=32), compared to 89% reoccupancy following an unsuccessful year (n=85).

Reuse rates for the nesting territories in the other study plots could not be determined, since it was not possible to assess which ponds were within the same territory in three brief visits by helicopter. Instead, frequency of use of ponds has been presented (Table 19). For all five study sites combined, just 16% of the ponds were occupied in

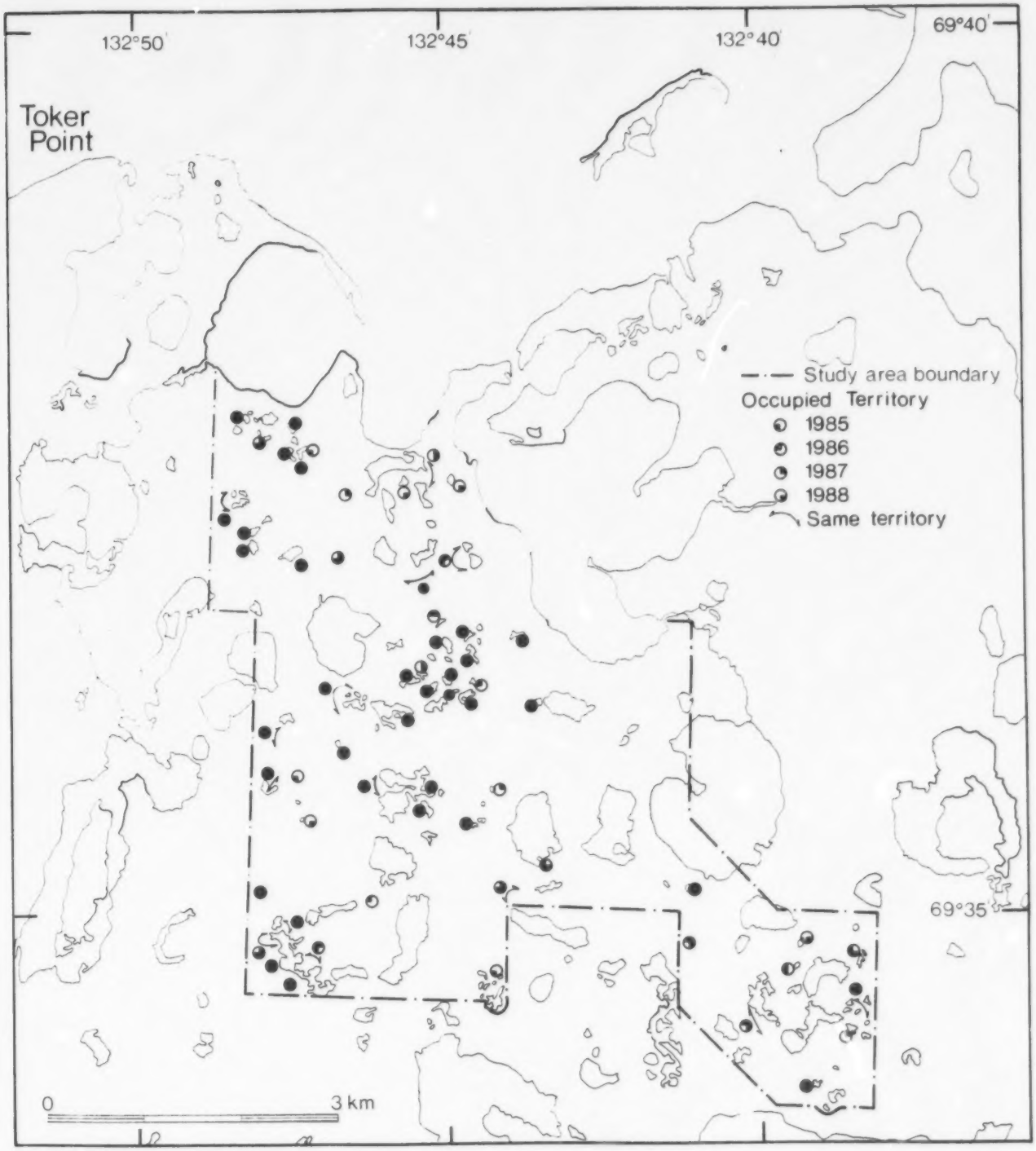

Figure 12. Location of Red-throated Loon nesting territories in the Toker Point study plot and their frequency of use.

Table 19. Frequency of times ponds were used for nesting by Red-throated Loons from 1985 to 1988[1].

Study plot	One year		Two years		Three years		Four years	
	No. of ponds	(%)	No. of ponds	(%)	No. of ponds	(%)	No. of ponds	(%)
Toker Point	30	(38)	12	(15)	12	(15)	25	(32)
Atkinson Point	43	(51)	13	(15)	11	(13)	17	(20)
Nuvorak Point	59	(47)	36	(29)	18	(14)	12	(10)
Husky Lakes	33	(43)	15	(19)	20	(26)	9	(12)
King Point	44	(42)	21	(20)	25	(24)	14	(13)
All study plots	209	(44)	97	(21)	86	(18)	77	(16)

[1]Includes ponds that were Occupied, but not Active Territories.

all four years, while 44% of the ponds were used in only one year. Frequency of reuse was highest at Toker Point and lowest at Nuvorak Point (32% and 10% occupancy respectively in all four years). Breeding success had no effect on whether a pond was reused the following year (X^2 tests, 1df, $p>0.3$) (Table 20).

Descriptions of the ponds, nest sites and nests were completed for 68 ponds with Red-throated Loon nests in the Toker Point study plot between 1985 or 1988. For comparison, 40 bodies of water not used by Red-throated Loons for nesting were also described. In the four other study plots, partial descriptions were done during the aerial surveys, then augmented by information obtained from slides taken during the aerial surveys. The descriptions have not yet been analyzed.

3.14 Breeding statistics for the Pacific Loon

The number of pairs of Pacific Loons occupying territories within the Toker Point study plot remained fairly constant between years, ranging from 44 pairs in 1985 to 39 pairs in 1986 (Table 21; Fig. 13). In most cases, we did not search for their nests. Thus, whether or not a territory was active was based on either behaviour or sighting of a chick. Accordingly, we recorded the lowest number of active territories in 1986 and the highest number in 1987 (17 and 39 active territories respectively). Only 18% of the pairs that attempted to nest in 1986 were successful resulting in only three young near fledging. Although more pairs attempted to nest in 1987 and 1988, their breeding success remained low at 0.2 fledged young/active territory.

Table 20. Effect of breeding success on reuse of the same pond the following year[1].

Study plot	Successful pairs		Unsuccessful pairs	
	Number	% that used same pond following year	Number	% that used same pond following year
Toker Point	31	81	86	76
Atkinson Pt.	51	72	34	68
Nuvorak Pt.	48	64	62	56
Husky Lakes	46	70	37	59
King Point	72	68	28	64

[1]No significant difference in reuse of the same pond in a year following a successful versus an unsuccessful breeding attempt (X^2 tests, 1df, $p>0.30$). Includes pairs that occupied a pond, but did not lay eggs.

Table 21. Breeding statistics for the Pacific Loon at Toker Point from 1985 and 1988.

		Year			
		1985	1986	1987	1988
Occupied territories[1]	- Number	44	39	43	43
	- Density (no./km^2)	1.7	1.5	1.6	1.6
Active territories[2]	- Number	26	17	39	34
	- Density (no./km^2)	1.0	0.6	1.5	1.3
Young near fledging	- Number	18	3	9	8
	- Density (no./km^2)	0.7	0.1	0.3	0.3
Breeding success (young/active territory)		0.7	0.2	0.2	0.2
Successful pairs	- Number	14	3	7	6
	- Percent	54%	18%	18%	18%

[1]A territory was considered occupied if a pair of loons was present until at least mid-July.
[2]A territory was considered active if eggs or young were found or if nesting behavior was observed.

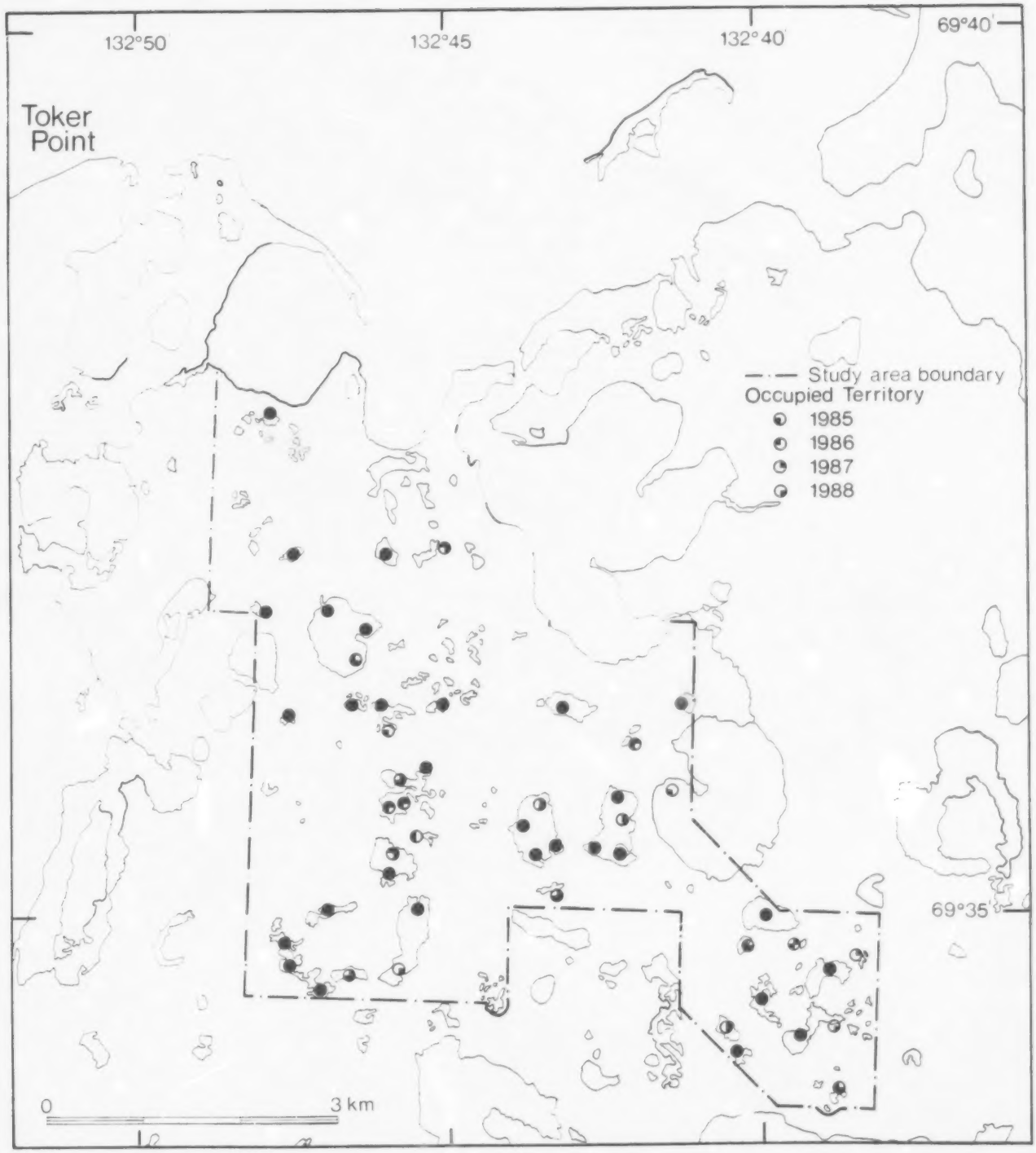

Figure 13. Location of Pacific Loon nesting territories in the Toker Point study plot from 1985 to 1988 and their frequency of use.

4.0 DISCUSSION

4.1 Density of resident loon pairs

The density of loon pairs varied within the study area with the highest densities occurring on the north side of the Tuktoyaktuk Peninsula (0.87 to 1.72 pairs/km^2), and lower densities occurring inland by the Husky Lakes (0.69 pairs/km^2) and along the Yukon north coast (0.56 pairs/km^2). In comparison, Bergman and Derksen (1977) reported 0.6 to 0.8 pairs/km^2 at Storkersen Point on the Alaskan Beaufort Sea coast.

During the nesting season at Toker Point, there were no flocks of non-breeding Red-throated Loons, such as described by Reimchen and Douglas (1980) on the Queen Charlotte Islands. All of the loons were paired and on territories. Bergman and Derksen (1977) likewise saw no flocks of non-breeders at Storkensen Point, Alaska. However, most years during this study 20% to 30% of the Red-throated Loon pairs did not nest (Table 3). Some of these non-breeding pairs may have been immature birds that had established a territory, but were not ready to breed. Lehtonen (1965 in Davis 1972) speculated that immature Arctic Loons in Finland establish a nesting territory a year prior to laying eggs. This could be an adaptation to the short arctic ice-free period for rearing young, since it would reduce the amount of time required to establish a territory the following spring (Davis 1972).

4.2 Productivity

The productivity of the Red-throated Loon in the Canadian Beaufort Sea region from 1985 to 1988 averaged 0.66 fledged young per

nesting pair (Tables 5 and 22). This value was very similar to the productivity found on Orkney and Foula, Shetland Islands by Furness (1983) and Booth (1982), although studies elsewhere on the Shetland Islands have indicated lower productivity (0.35 to 0.45 young per nesting pair (Bundy 1976; Bundy 1978; Gomersall 1986)). On the other hand, a higher reproductive rate has been reported in Sweden and Finland (0.8 to 1.15 young per nesting pair) (Lokki and Eklöf 1984), as well as on the Queen Charlotte Islands (0.86 young per nesting pair) (Douglas and Reimchen 1988).

Evidence suggests that the Red-throated Loon population in the Beaufort Sea region grew during the study period. At Nuvorak Point study plot, the number of resident pairs of loons rose from 44 pairs in 1985 to 70 pairs in 1988, while at the other four sites the increases varied from 3 to 15 pairs. Some of this was likely due to us finding additional territories which we had missed in previous years. Ground truthing of an aerial survey in the first year of the study indicated that we had missed 10% of the nests. Since the loons tend to renest in the same pond each year, fewer nests were likely missed in subsequent years. This would artificially raise the pair count, particularly during the first two or three years of the study. However, the near doubling of the number of pairs at Nuvorak Point must have been also due in part to a real growth in numbers.

Further evidence in support of a growing population was the productivity of the loons which ranged from 0.51 to 1.07 young per nesting pair from 1984 to 1988. Although the survival rate of the

Table 22. A comparison of the productivity of the Red-throated Loon in the Canadian Beaufort Sea region to other areas.

Region	Young fledged per nesting pair	Year	Source
Shetland	0.41	1973-74	Bundy 1976
Shetland	0.35	1976	Bundy 1978
Shetland	0.45	1981-82	Gomersall 1986
Foula, Shetland	0.65	1956-81	Furness 1983
Orkney	0.67	1973-80	Booth 1982
Sweden	0.8	1979-81	Arvidsson 1981 in Lokki and Eklöf 1984
Finland	1.15	1979-82	Lokki and Eklöf 1984
Queen Charlotte Islands	0.86	1976-86	Douglas and Reimchen 1988
Canadian Beaufort Sea	0.66	1985-88	This study

Red-throated Loon is unknown, Nelsson (1977) calculated that the Arctic Loon (Gavia arctica) in Sweden would maintain its population level if it produced 0.4 to 0.5 fledged young per pair each year. Assuming the mortality rate for the Red-throated Loon is similar, and that they return to their natal breeding grounds to nest as banding studies by Furness (1983) suggest, the reproductive rate measured during this study should result in a slight growth in the local population.

4.3 Factors affecting productivity

As expected in an arctic environment, the breeding effort and success of the Red-throated Loon fluctuated from year to year. The percentage of resident pairs that attempted to nest varied from 58% in 1986 to 87% in 1984 (Table 4); similarly, the percentage of breeding pairs that were successful varied from 45% in 1986 to 72% in 1984 (Table 5). The following is a discussion of the primary factors which affected productivity each year, with emphasis on the data from Toker Point from 1985 to 1988, for which there is the most ecological information.

The poor breeding effort in 1986 coincided with a spring thaw that was nearly two weeks later than usual (Table 23). Only 63% of the resident loon pairs at Toker Point lay eggs that year compared to 78 to 86% in other years.

It is unknown whether the lower breeding effort which follows a late spring thaw is due to nutritional or physiological contraints.

Table 23. The timing of nest initiation by the Red-throated Loon at Toker Point in relation to spring thaw.

Year	Date reach 30 thawing degree days[1]	Date shallow ponds open	Date coastal lead of >100 m	Mean date of nest initiation	Percentage of pairs that nested
1985	31 May	1st week of June	20 June	21 June	86
1986	18 June	16 June	1 July	4 July	63
1987	9 June	7 June	29 June	25 June	78
1988	4 June	25 May	22 June	21 June	84

[1]Data for Tuktoyaktuk airport (Atmospheric Environment Service).

Fewer Mallards nest when they are nutritionally stressed; they also lay smaller eggs (Elridge and Krapu 1988). In an attempt to determine if the Red-throated Loons were nutritionally stressed following the late spring break-up in 1986, I compared egg sizes in 1986 with 1985 and 1987, using the weight of eggs up to two days old. There was no significant difference between years in the weight of the eggs (Kruskal-Wallis ANOVA, 2df, p=0.36). The egg weights averaged 78.0 gm (n=45), 76.4 gm (n=48) and 77.3 gm (n=46) in 1985, 1986 and 1987 respectively. On the other hand, because the ice-free season in the study area is so short relative to the length of time required for a Red-throated Loon to fledge, a late spring may inhibit the loon's reproductive physiology. Barry (1962) found that the Atlantic Brant's ovaries regressed in size without ovulating, if spring thaw was too late. Being an arctic nesting bird, the Red-throated Loon may have a similar physiological reaction to a late breeding season.

The percentage of eggs that hatched at Toker Point tended to be low and to vary greatly from year to year. Hatching success ranged from 14% to 55% between 1985 and 1988 with an average of only 31% of the eggs hatching. Most of the eggs that did not hatch, disappeared from the nest with no sign of what happened, although they were presumably taken by predators. The major predators were the arctic fox, Parasitic Jaeger and Glaucous Gull, for which there is evidence of them taking loon eggs on 7, 10 and 10 occasions respectively. Although none were seen doing so, the Common Raven and Sandhill Crane, both of which were seen daily in the study area, likely also took loon eggs. We saw ravens take other

similar large birds eggs such as Greater White-fronted Goose eggs. Davis (1972) reported Sandhill Cranes taking loon eggs at Hudson Bay. None of the loon eggs were lost due to flooding of the nest, which has been identified as a source of mortality in other areas (Gomersall 1986; Lokki and Eklöf 1984; Douglas and Reimchen 1988), and only eight eggs over the four years failed to hatch because they were addled or infertile. Thus, predation was the primary factor affecting hatching success.

There was an inverse relationship between the hatching success of the loon eggs and the number of foxes in the study area. Hatching success was highest in 1988 when there were very few foxes, whereas it was lowest in 1987 when foxes were significantly more abundant (Tables 6 and 12). Studies in Alaska likewise noted heavier losses of loon eggs in years when fox activity was high (Bergman and Derksen 1977; Schamel and Tracy 1985).

Annual fluctuations in egg losses could not be linked to avian predators, since unlike the fox population, there was no significant difference in the number of avian predators at Toker Point each year (Table 12).

Given the moderate number of foxes in the study area in 1986, egg predation was unexpectedly high. However, alternate food sources for both the foxes and avian predators were not as abundant in 1986 as in other years. Significantly fewer birds, including waterfowl, nested that year and very few young were produced (Table 14). Thus, with less food available, predator pressure on loon eggs was likely heavier. Similarly,

Pehrsson (1986) noted that the production of Oldsquaw ducklings doubled in rodent peak years and concluded this was best explained by predators shifting to alternate prey, such as eggs, when rodents were not as abundant. Peterson (1979) and Davis (1972) both found an increase in predation of Pacific and Red-throated loon eggs by foxes, jaegers and gulls when eggs from a nearby goose colony became less available to predators, either due to greater protection of the eggs by the geese just prior to hatch or due to hatch of the goose eggs.

Like the eggs, most of the Red-throated Loon chicks that did not fledge disappeared without any sign of what happened to them. Many of the deaths of the youngest chick may have been due to starvation (Furness 1983; Davis 1972; Braun et al 1968). Davis (1972) found that because the eggs of the Red-throated Loon hatched asynchronously, one chick had an advantage over the other in competing for the fish brought to them. Thus, the youngest chick of most broods starved to death. Predation was another factor causing chick mortality. On five occasions, a Glaucous Gull was seen picking up a loon chick from a pond. The gull was successful in carrying away the chick in two incidents, but the other three attempts failed when a close pass by an adult loon resulted in the Glaucous Gull dropping the chick. Although we never saw a Parasitic Jaeger take a loon chick, on several occasions we did see them try to take fish from adult loons that were carrying the fish to the nesting pond. On one occasion a Sandhill Crane was observed unsuccessfully trying to catch a loon chick. Northern Harriers and Rough-legged Hawks may prey on loon chicks in years when microtine

rodents are scarce. Other potential predators of loon chicks were the Common Raven, Bald Eagle (Douglas and Reimchen 1988), and Peregrine Falcon (White and Cade 1971), although the latter two species were only occasional visitors at Toker Point.

The percentage of chicks that fledged at Toker Point was fairly consistent at 62% to 67% in all years except 1988 when only 25% to 38% of the young fledged. A primary factor that contributed to the greater loss of chicks in 1988 may have been heavier predation by avian predators. Like the Red-throated Loon, the Glaucous Gull and Parasitic Jaeger produced more chicks in 1988 than in the previous three years (Table 13). With more chicks to feed, pressure to take loon eggs and chicks was likely heavier. The highest mortality rate of loon eggs and chicks occurred from 1 to 28 July which coincided with when Glaucous Gull and Parasitic Jaeger chicks were most abundant (Fig. 14). Parasitic Jaegers hatch in the first week of July, while Glaucous Gulls hatch from early to mid-July (this study; Martin and Barry 1973; Alexander et al. 1988). Furthermore, loon chick mortality in 1988 was highest in the first week after hatch (38%), the period when loon chicks are most vulnerable to avian predators (Fig. 9). The main defense of a loon chick from avian predators is to dive, but for the first few days after hatch it can only dive a few centimetres below the surface for a few seconds. Thus, if left unattended, it is easy prey for birds.

In years such as 1988, when a large percentage of eggs hatch, the high mortality rate of chicks could be due to greater competition for a limited food resource. Pehrsson and Nyström (1988) found that Oldsquaw

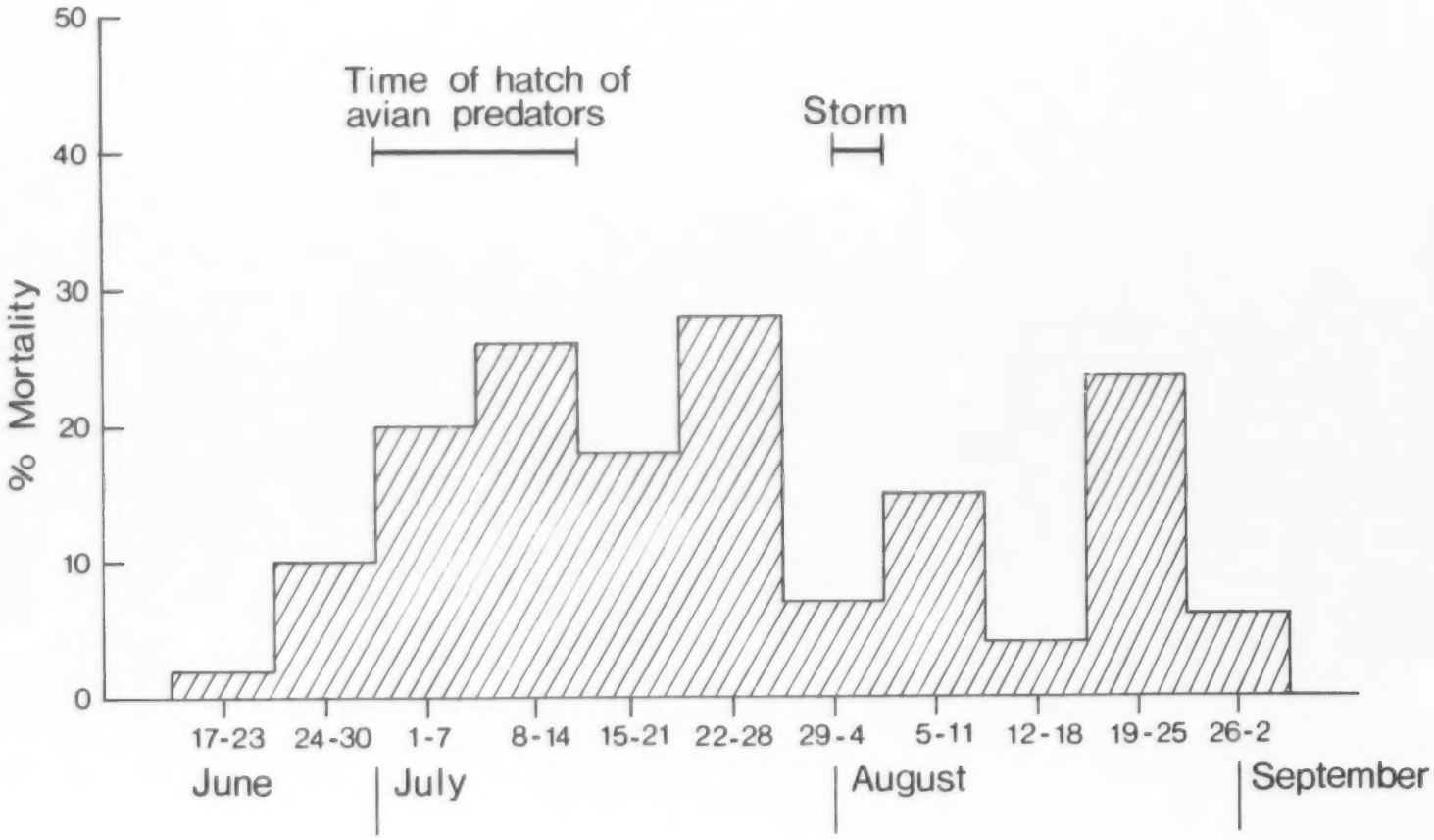

Figure 14. Effect of predator hatch and a mid summer storm on mortality rate of Red-throated Loon eggs and chicks at Toker Point study plot in 1988.

duckling mortality was higher in years when duckling production was high, and attributed this to the ducklings depleting their major food source, the fairy shrimp. The higher mortality rate of chicks could also be due to a food supply that has already been depleted because of other factors. The recent poor reproductive success of Red-throated Loons on the Shetland Islands has been attributed to a decline of sand-eels (Ammodytes sp), the loons primary food source (Bourne 1989). However, at Toker Point, feeding rates of loon chicks did not differ significantly between years, which suggested that the food supply was adequate despite the larger number of chicks in 1988. Furthermore, the results of the beach seining indicated that there were more fish the size and species used by the Red-throated Loon in 1988 than in 1987. Thus, the high mortality rate of chicks in 1988 was unlikely due to a shortage of food.

The severe storm from 1 to 4 August seemed to have only a minor immediate affect on the survival of the Red-throated Loon chicks. The mortality rate during the storm was actually lower than either before or after that period (Fig. 14). Only one chick death was linked directly to the storm: a five-day old chick which likely drowned when its nesting pond was inundated by high surf caused by winds over 50 kph. The four chicks that disappeared during the week following the storm could also have died as a result of the four-day storm. Dunn (1975) reported many tern chicks slowly starved to death following a three-day storm despite a return to favorable foraging conditions. He attributed the deaths to the chicks being so weak from food reduction during the storm that they

were unable to beg vigorously enough for food to elicit the appropriate response from their parents.

Flooding which has been identified as a cause of hatching failure for Red-throated Loons in several other areas (Douglas and Reimchen 1988; Gomersall 1986; Lokki and Eklöf 1984; Cyrus 1975) did not occur at Toker Point during the study period. However, at Nuvorak Point study plot the stormtide that occurred in early August of 1988 flooded about 20% of the ponds that had active Red-throated Loon territories. This flooding seemed to have a positive effect on breeding success, for the 17 nesting pairs on flooded ponds produced 0.59 young per active territory compared to 0.38 for the entire study plot. In the previous three years, that portion of the Nuvorak study plot always had a lower breeding success than the rest of the study plot. Given the shallowness of these ponds (<1 m), the flooding may have enhanced the survival of the loon chicks by making it easier for them to escape predation.

The data from Nuvorak Point study plot would suggest that low water-levels contributed to lower productivity. However, at Toker Point drought conditions seemed to have very little effect on breeding success. Water-levels dropped the most in 1985 and 1988, two of the most productive years at Toker Point, and remained most stable in 1986 when productivity was very poor. In the dry years several nests initially surrounded by water became isolated from the pond by as much as 12 metres making the nests more accessible to foxes and making escape for the adult bird difficult. Yet the loons continued to incubate despite having to crawl several metres through the mud to reach the

nest. In 1988, a chick was successfully reared to fledging on a pond that by August was covered less than 10% with water (an area of about 200 m^2). At another nest pond, that was covered only about 10% with water at hatch (25 m^2 of pond had water), the loon lead its chicks 30 m across the wetland to a deeper pond. At yet another pond a chick was successfully hatched despite the fact that all but about 6 m^2 of the pond had dried up. Gomersall (1986) noted that drought conditions seemed to have no affect on egg losses of Red-throated Loons on the Shetland Islands. The apparent tolerance of this loon species to low water-levels may be due to its ability to take-off from land (Godfrey 1966).

The intensive monitoring of the loons by observers on the ground at Toker Point had a marked effect on breeding success. In 1984, when only one search for incubating loon was conducted at Toker Point and it was done by helicopter, Toker Point had the highest breeding success of all five study plots. In the following four years, when Toker Point was checked every three to five days by observers on foot, it had the lowest productivity in the study area (only exception was Nuvorak Point in 1985; Fig. 4). The impact of the ground observers was most severe in 1985, 1986 and 1987 when nests were visited every five days. The resulting hatch was only 38%, 17% and 14% of the eggs respectively. In 1988, most of the nests were viewed from a distance (>150 m) rather than visited, and 55% of the eggs hatched. Occasionally an observer saw a Glaucous Gull or Parasitic Jaeger take a loon egg or chick, but most eggs and chicks disappeared between visits with no sign of what

happened. Arctic foxes may have followed our scent to the nest sites, but we have no direct evidence to support this. Other studies have also noted that human visitations to nests have contributed to increased predation of eggs (Bart 1977; MacInnes and Misra 1972).

The pattern of annual fluctuations in breeding success at Atkinson Point was very similar to that at Toker Point except in 1984, which was the year that ground observers were at Atkinson Point instead of Toker Point. Again the lower success rate in 1984 was likely linked to the disturbance caused by the observers working on the ground. Nuvorak Point had similar patterns of breeding success to Toker Point, except in 1988 when success was much lower at Nuvorak relative to the other study plots. Unlike the other areas, King Point maintained a relatively high success rate in 1986 and 1987, although nest attempts were low at King Point in 1986, like elsewhere that year. Breeding success at Husky Lakes was much more consistent from year to year than it was at the other study plots. The reason for these differences between study plots in the pattern of annual fluctuations in breeding success are beyond the scope of this study, but the fact that they do differ must be taken into consideration in the post-development phase of the monitoring study.

The annual fluctuations in both breeding effort and hatching success of waterfowl at Toker Point were similar to those of the Red-throated Loon (Table 14). Like the loon, waterfowl nests were least abundant in 1986 when spring break-up was delayed about two weeks. Hatching success also followed a similar pattern to that of the loon.

Despite the large number of nest attempts in 1987 (Table 14), few young were seen due to heavy predation by arctic foxes (only 33 waterfowl young in 1987 compared to 226, 70 and 236 young in 1985, 1986 and 1988 respectively). It is not known whether the waterfowl experienced high mortality of their young like the Red-throated Loons did in 1988, since waterfowl usually lead their young away from the nesting area, thus making it difficult to assess annual production. One of the reasons why the loon is the preferred species for the monitoring program is that the young remain on the breeding pond until they can fly; hence more accurate data on annual production can be obtained. The fact that the annual changes in breeding effort and hatching success of waterfowl followed the same pattern as those for the Red-throated Loon, is further proof of the suitability of the Red-throated Loon as an indicator species.

4.4 Breeding site tenacity

The degree of reoccupancy of the same nesting ponds by Red-throated Loons each year may be an indication of the amount of additional nesting habitat there is available for the Red-throated Loons. Toker Point had the highest frequency of reoccupancy of ponds (Table 19), thus likely had the least amount of suitable habitat for additional breeding pairs. Nuvorak Point, conversely, had the most unused nesting habitat. Should a port be developed in the Beaufort Sea region, the impact on loons would likely be less severe if it was located in an area where the suitable nesting habitat was not full to capacity.

Only the pond site tenacity and not the territorial site tenacity could be determined for the study plots surveyed by helicopter. An analysis of territory site tenacity, as was done at Toker Point (Section 3.13), would likely show that there is much less unused nesting habitat than the data on pond site tenacity suggests. This may be particularly true of Atkinson Point where the ponds are numerous but clustered close together.

On the Shetland Islands, 65% of known breeding lochs (n=157) were used in three consective years (Gomersall 1986), compared to our study area where 34% of the ponds were used three or more consecutive years. The frequency of reuse of lochs in Shetland was more closely comparable to the 64% reuse of occupied territories in three or more years that we found at Toker Point. At McConnell River on the Hudson Bay coast, Davis (1972) reported that 77% of the nesting territories (n=39) were used three years in a row.

Assuming the same pair returns to a pond each year, as banding evidence suggests (Furness 1983), there was no significant difference in the tendency for loons to reuse either the same pond or the same nesting territory following a successful year than an unsuccessful year (X^2 tests, 1df, $p>0.30$). Davis (1972) found a trend towards greater re-use following a successful year, but the difference was not statistically significant. However, on the Shetland Islands the effect of hatching success on reoccupancy of the lochs the following year was significant (Gomersall 1986).

4.5 Phenology

The Red-throated Loon arrives in the Beaufort Sea region in late May and early June (Koski and Tull 1981). Before their nesting ponds thaw, they have been seen in the offshore leads of open water, particularly west of Tuktoyaktuk (Alexander et al. 1988; Barry and Barry 1982; Barry et al. 1981), as well as at the mouth of the Kugaluk River (P. Voudrach, pers comm.). In 1974 and 1986, two years when there was very little open water in the Beaufort Sea during spring migration, T. Barry (pers comm.) found thousands of Red-throated and Pacific loons on the Mackenzie River over 200 km upstream from the coast (between the mouth of the Travaillant River and the Ontaratue River). In the two years that we arrived on the study area before the loon nesting ponds thawed (1984 and 1986), nearly all of the loons occupied the ponds within a day of thawing (6 June in 1984 and 15 to 18 June in 1986). Bergman and Derksen (1977) likewise noted that the loons arrived at Storkersen Point, Alaska concurrently with thawing of their nesting ponds.

From 1984 to 1987, an average of 17 days elapsed between arrival of the loons on the nesting ponds and laying the first egg (assuming the loons arrived on the nesting ponds within a day of thaw each year, as they did in 1984 and 1986). Petersen (1976) reported an 11 to 13 day delay between major occupancy of ponds and egg-laying in Alaska (n=4). Yonge (1981), who found a similar delay of two weeks for the Common Loon in northern Manitoba, noted that territorial aggresiveness in spring is one of the releases of gonadal cycles in birds (Lofts and Murton 1973 in Yonge 1981).

In 1988, the period of time between thawing of the ponds and egg laying was 23 days. Although the ponds became ice-free about a week earlier on 29 May that year, the mean date of clutch initiation remained the same as in years when the timing of the thaw was later. The Red-throated Loon may not arrive on its nesting grounds in the Beaufort Sea region until the first week of June even when its nesting ponds thaw earlier. Barry (1962) found that Atlantic Brant arrived on their arctic nesting grounds at the same time each year ,regardless of how advance spring was. Thus, the timing of egg-laying at Toker Point seems dependent on when the loons arrived in the region in years when spring thaw is early, but dependent on when the nesting ponds thawed when the season is late.

The primary factor affecting how long it takes the Red-throated Loon to initiate nesting in spring is likely physiological. Delays due to social behaviour associated with pair formation, and finding and defending a nesting territory would be minimized, since the Red-throated Loon likely pairs for life (Cramp et al. 1977) and usually returns to the same nesting territory each year (Davis 1972; Furness 1983). By minimizing the length of time required to lay their eggs, the Red-throated Loon is better adapted to nesting in areas such as the Beaufort Sea region where the nesting ponds are ice-free for only a short period of time.

In regions where the open-water season is much longer, the period between arrival and nest initiation is also longer. Schamel and Tracy (1985) reported a 30-day delay at Cape Espenberg in western Alaska,

compared to the 17 day period in our study area. Similarly, on the Queen Charlotte Islands, although the loons arrived in mid-april, they did not lay eggs until 10 May to 20 June (Douglas and Reimchen 1980). In Shetland, loon pairs arrived in the breeding area at least two months before clutch initiation (Bundy 1976).

Eggs within a clutch were laid 2 to 3 days apart at Toker Point (n=4). Bundy (1976) (sample size not reported) and Davis (1972) (n=4) found that the eggs were laid 2 days apart; however, Douglas and Reimchen (1988) noted that the eggs in four clutches on the Queen Charlotte Islands were laid 1 day apart. At Toker Point, the eggs hatched 1 to 3 days apart (n=7), whereas Davis (1972) found that the eggs within a clutch always hatched 1 day apart (n=22).

Length of incubation varied from 24 to 27 days (n=13) in our study area, compared to 24 to 29 days (n=19) on the Shetland Islands (Bundy 1976), and 24 to 31 days (n=11) on the Queen Charlotte Islands (Douglas and Reimchen 1988). It appears that the minimum length of time required for Red-throated Loon eggs to hatch is 24 days, although they may take up to a week longer to hatch. The presence of the observers may have contributed to the vaiation in the length of incubation. An observer is visible for several kilometres on the tundra and some loons got off their nests when an observer was over a kilometre away. Thus incubation was sometimes interrupted for an extended period of time while an observer was investigating other nesting territories in the area. The subsequent cooling of the eggs would slow their development. Extended incubation periods due to disturbance which interrupted

incubation has been reported previously in Tufted Puffins (Pierce and Simons 1986).

The number of days required for chicks to fledge at Toker Point ranged from 43 to 52 days (n=10), compared to 38 to 48 days (n=25) on the island of Unst, Shetland (Bundy 1976), and 46 to 50 days (n=5) on the Queen Charlotte Islands (Douglas and Reimchen 1988). The average period of time from egg-laying to fledging of the young was nearly the same at Toker Point as it was for areas with much longer ice-free periods. Young Red-throated Loons fledged an average of 75 days after the onset of clutch initiation on the Queen Charlotte Islands where the lakes are ice-free at least 170 days, compared to 74 days for the young to fledge at Toker Point where there are only about 110 ice-free days.

At Toker Point, the number of days required for development of the loon chicks varied by at least 9 days. This difference may have been partly due to the amount of food each chick received. Slower growth rates in Red-throated Loon chicks not receiving adequate food have been reported by Davis (1972).

Chicks at Toker Point took an average of four days longer to fledge in 1988 than in the previous three years: 50 days in 1988 (n=3) compared to 46 days from 1985 to 1987 (n=7). Observation from a blind twice a week indicated that chicks were fed the same number of fish per day in 1988 as in the previous three years, so that one would expect a normal rate of development for nutritional reasons. However, the four-day storm in mid summer of 1988 which had offshore winds of 50

to 70 kph and heavy surf likely hindered adult loons from catching and carrying fish inland to feed their chicks. This interuption in feeding for several days would slow the rate of development of the chicks. The reduction of growth during strong winds and rain has been noted in Common Terns (Dunn 1975).

Chicks at Toker Point fledged between 24 August and freeze-up of the nesting ponds which occurred in late September. I assumed that four chicks which would have fledged after freeze-up did not survive, but if they did, fledging occurred as late as 4 October.

4.6 Determining when to survey for incubating loons

During the first two years of the study, methods of determining clutch initiation were investigated in order to establish the optimum time to survey for incubating loons in future years of the monitoring program. The date of clutch initiation can be calculated by back-dating if one knows the age of the egg. Thus, two techniques for aging eggs were tried at Toker Point, both of which measured the change in density of the egg as it developed.

The floatation method of aging eggs proved most accurate. By placing an egg in a container of water, one could estimate its age to within 4 days (Table 9), whereas the 95% Confidence Interval for the age derived from weighing and measuring the size of an egg was approximately ± 7 days. The reason why aging eggs, by measuring their weight, length and width was so imprecise was because loon eggs vary in shape so much. The same constant (k=0.507) was used to calculate the volume of each egg

regardless of its shape, so that the volume was inaccurate for certain egg shapes. As a result, the variance in the density of eggs of a given age was very large. In order to improve the accuracy of this method of aging eggs one could develop different constants for several classes of egg shapes in order to calculate the volume, or one could obtain a more accurate estimate of the volume by measuring the amount of water displaced.

As was discussed in Section 4.3, visiting the Red-throated Loon nests to either weigh or float the eggs caused a notable increase in predation. Since this study is intended to monitor impacts of industrial development, it is essential to minimize the effect of the researcher on the indicator species. Thus, it is recommended that for the duration of the monitoring study, the timing of the aerial surveys for incubating loons be determined by when the nesting ponds thaw each year rather than by aging the eggs. See Section 4.7 for details.

4.7 Determining when to survey for chicks near fledging

The timing of chick mortality and fledging was examined to determine the optimum time to collect data on breeding success. Ideally, the surveys should be conducted when the chicks are old enough that they will all survive to fledging. Previous studies indicate that most losses of Red-throated Loon chicks occur within two weeks of hatch (Bundy 1976; Gomersall 1986; Bergman and Derksen 1977). At Toker Point, 66% of the losses occurred prior to the chicks reaching 15 days of age, while another 20% of the losses occurred when the chicks were in their

third week. Of the remaining 14% lost after 3 weeks, we were able to predict 8% of the losses based on the estimated age of the chick and the timing of freeze-up, which left an additional 6% (0 to 1 chick lost per year) that occurred after 3 weeks and were unpredictable. Due to the substantial number of chicks lost during their third week in some years at Toker Point, the surveys for chicks near fledging should not be conducted until the majority of chicks are over three weeks old. At Toker Point, surveys conducted after 17 August fulfilled this requirement in all years except 1986 when nest initiation was two weeks late. The other limitation on the timing of the census of chicks is the date when they start to fledge. The earliest record of fledging at Toker Point was 24 August in 1985. Thus, in a typical year, the aerial survey for chicks should be conducted from 18 to 22 August.

In order to predict the number of chicks lost due to their nesting ponds freezing prior to the chicks fledging, the size of each chick was estimated. Their age was then calculated based on the formula derived from the ground surveys at Toker Point (Section 3.4). For example, a chick two-thirds adult size would be 21 ± 2 days old. With knowledge of the date of freeze-up, and assuming the chicks fledged at 46 days, I could then assess how many chicks likely died due to freeze-up. Accordingly, two chicks in 1985 and two in 1988 were assumed to have died prior to fledging due to the shallow ponds freezing over before the chicks were 46 days old. Also, a heavy snowfall on 26 August in 1984 which temporarily froze many of the shallow ponds at Toker Point and Atkinson Point, may have killed as many as 22 chicks.

Some Red-throated Loon chicks may survive an early freeze-up by moving to open water on a larger waterbody. On several occasions during this study, chicks moved up to 300 m across land to another waterbody, usually due to low water-levels on the nesting pond, and on at least one occasion, due to disturbance. Movement by Red-throated Loon chicks to another waterbody has also been reported by Furness (1983), Bergman and Derksen (1977) and S. MacDonald (pers. comm.). None of the movements reported were due to the nesting pond freezing. However, given the Red-throated Loon chick's ability to tranverse land, it may be able to survive an early freeze-up provided there are larger waterbodies nearby that remain open long enough for the chick to fledge.

4.8 Replacement clutches

The proportion of renests after failed clutches is likely dependent on how early the loons are able to lay eggs. At Toker Point, the percentage of pairs that laid a replacement clutch after loosing the first was lowest in the year when spring thaw, hence nest initiation, was two weeks late, and highest in the year when spring thaw was earliest (22% and 40% respectively). Furthermore, on Unst, Shetland Islands where egg-laying starts a month earlier, the percentage of renests is much higher: Bundy (1976) reported that 64% of the lost clutches were replaced (n=22). Thus, the earlier the date of nest initiation, the greater the proportion of renest after failed clutches.

The length of time between loss of the original clutch and laying eggs of the replacement clutch averaged 10 days (n=10) at Toker Point.

Schamel and Tracy (1985) reported a 12 to 15 day period for three pairs of Red-throated Loons in Alaska and confirmed the replacement clutches were laid by the same pair of loons on their original nesting territory. They suggested that the time between destruction of the first nest and laying the second clutch was minimized, because the loons remained paired with the same mate, as well as remained on the same nesting territory. Thus, very little social behaviour was needed prior to renesting.

4.9 Pacific Loon

The breeding success of the Pacific Loon at Toker Point was low with only 0.2 young fledged per active territory in the last three years of the study. In comparison, Eriksson (1987) reported 0.4 young per breeding pair in southwest Sweden, although Sharrock (1976 in Nilsson 1977) observed only 0.25 young per pond in Scotland. The low breeding success at Toker Point may have been partly due to disturbance. The Pacific Loon was much more sensitive to our presence on the study area than the Red-throated Loon. During incubation, the Pacific Loon was disturbed by people and left the nest at a greater distance than the Red-throated Loon. It also took the Pacific Loon a much longer time to return to the nest. When we hid from view, the Red-throated Loon usually returned to the nest within 5 to 10 minutes, whereas the Pacific Loon remained in the centre of the pond preening, diving and mock-sleeping often 30 to 45 minutes. This difference in reaction to our presence likely resulted in a greater proportion of Pacific Loon eggs being taken by avian predators or becoming addled from exposure.

The late spring thaw in 1986 had a greater effect on the productivity of the Pacific Loon than the Red-throated Loon. Half as many Pacific Loons nested in 1986 compared to other years (Table 21), whereas the breeding effort by the Red-throated Loon dropped by only a quarter (Table 6). Likewise, only a quarter of the usual number of Pacific Loon chicks fledged in 1986 (3 young fledged in 1986 compared to an average of 12 in the other three years), whereas half the usual number of Red-throated Loon chicks fledged (8 young fledged in 1986 compared to an average of 15 in the other three years). The Red-throated Loon is better adapted to a short ice-free season than the Pacific Loon, as their more northerly distribution would suggest. The Red-throated Loon nests on small shallow ponds that thaw earlier than the larger ponds and lakes used by the Pacific Loon (this study; Davis 1972), so they are able to occupy a nesting territory and lay their eggs earlier. Furthermore, Red-throated Loon chicks fledge about two weeks earlier than Pacific Loon chicks (Cramp et al. 1977).

Despite the tendency for Red-throated Loons to select smaller more shallow ponds for nesting, there was some competition with the Pacific Loon for the same ponds at Toker Point. Three ponds alternated from year to year between being occupied by Red-throated and Pacific loons. At four other sites, we observed frequent interspecific territorial encounters, although these sites remained Red-throated Loon nesting territories throughout the study. Davis (1972) likewise reported interspecific territorial encounters at Hudson Bay.

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Appendix A. Density of Red-throated Loon nesting territories and chicks near fledging at five study plots in the Beaufort Sea region from 1984 to 1988.

	Year	Density by area (no. per km^2)				
		Toker Point	Atkinson Point	Nuvorak Point	Husky Lakes	King Point
Occupied territories[1]	1984	1.62	1.18	0.76	0.60	-
	1985	1.65	1.06	0.68	0.62	0.51
	1986	1.65	1.21	0.77	0.66	0.48
	1987	1.92	1.45	1.06	0.71	0.60
	1988	1.77	1.42	1.08	0.84	0.67
Active territories[2]	1984	1.46	1.00	0.64	0.54	-
	1985	1.42	0.79	0.43	0.48	0.34
	1986	1.04	0.64	0.43	0.43	0.26
	1987	1.50	1.15	0.82	0.57	0.44
	1988	1.50	1.27	0.82	0.64	0.46
Young near fledging	1984	1.96	1.12	0.62	0.42	-
	1985	0.92	0.64	0.23	0.52	0.35
	1986	0.31	0.42	0.14	0.21	0.22
	1987	0.50	0.97	0.57	0.34	0.42
	1988	0.77	1.39	0.31	0.36	0.31
Area surveyed (km^2)[3]		26	33	65	56	96

[1]Occupied territory - A territory was considered occupied if a loon was present during at least one survey, the site was suitable loon nesting habitat, and there was no evidence that the site was part of a nearby loon territory.
[2]Active territory - A territory was considered active if there were eggs or young, or fresh egg remains or dead chicks.
[3]In 1984, the area surveyed at Nuvorak Point was 55 km^2 and at Husky Lakes was 52 km^2.

Appendix B. Mean daily counts of predators at Toker Point during the breeding season from 1985 to 1988.

Appendix B1. Mean daily counts of predators in 1985.

Species	Mean number observed per day by 6-day intervals								
	June 17-22	June 23-28	June 29 -July 4	July 5-10	July 11-16	July 17-22	July 23-28	July 29 -Aug. 3	Aug. 4-9
Red Fox		0.17							
Common Raven	3.17	1.17	0.83	1.00		0.40	0.17	2.00	2.33
Eagle species				0.25			0.17		
Glaucous Gull	46.17	31.17	15.50	42.50	32.33	26.20	22.33	30.00	25.00
Gyrfalcon	0.17								
Long-tailed Jaeger	2.00	1.50	1.67	0.75	5.00	0.80			
Northern Harrier	0.50	0.33	0.67	0.25	0.67	0.20	0.17	1.50	0.67
Parasitic Jaeger	4.50	5.50	4.50	4.00	8.67	3.60	3.00	3.00	2.33
Peregrine Falcon		0.17		0.25	0.33				
Rough-legged Hawk	1.67	0.17	2.17	1.50	0.33	0.60	0.50	0.25	0.33
Sandhill Crane	8.33	8.17	5.83	6.50	5.00	3.80	4.50	4.75	2.67
Sabine's Gull	3.67	0.33	1.00	0.50	2.67	1.60	0.17		
Short-eared Owl					0.33				
Snowy Owl				0.25					
All species	70.17	48.67	32.17	57.75	55.33	37.20	31.00	41.50	33.33

*Blank indicates 0.00

Appendix 82. Mean daily counts of predators in 1986.

Species	Mean number observed per day by 6-day intervals								
	June 17-22	June 23-28	June 29 -July 4	July 5-10	July 11-16	July 17-22	July 23-28	July 29 -Aug. 3	Aug. 4-9
Arctic Fox	0.83		0.17	0.33	0.33	0.67	0.17	0.17	0.17
Common Raven	0.33	0.50	1.50	0.83	0.50	0.33	0.50	0.33	1.33
Glaucous Gull	19.67	26.33	26.17	19.67	47.50	23.17	52.83	28.00	31.00
Jaeger species					0.83				0.33
Long-tailed Jaeger	2.00	1.17	0.83	1.33	1.00	1.00			
Northern Harrier	1.00	0.83		0.17		0.17	0.50		0.33
Parasitic Jaeger	2.83	4.33	2.67	2.17	4.00	3.17	1.17	1.83	1.67
Peregrine Falcon		0.17	0.17		0.17				
Pomarine Jaeger	0.33								
Rough-legged Hawk	1.33	1.00	1.00	2.00	0.67	1.50	1.83	1.17	0.50
Sandhill Crane	11.17	6.67	3.50	6.67	8.17	5.00	4.50	5.00	4.50
Sabine's Gull	2.67	1.17	0.83			0.33	0.17		
Short-eared Owl	0.50			0.17	0.33		0.17		
Snowy Owl			0.17						
All species	42.67	42.17	37.00	33.33	63.50	35.33	61.83	36.50	39.83

*Blank indicates 0.00

Appendix B3. Mean daily counts of predators in 1987.

Species	Mean number observed per day by 6-day intervals								
	June 17-22	June 23-28	June 29 -July 4	July 5-10	July 11-16	July 17-22	July 23-28	July 29 -Aug. 3	Aug. 4-9
Arctic Fox	1.00	1.33	0.83	0.33	0.17	0.80		0.75	3.00
Arctic Wolf							0.50		
Common Raven	1.33	0.83	0.50	0.50	0.33		0.50	1.25	2.50
Glaucous Gull	26.67	17.83	30.50	26.83	31.17	21.40	32.50	39.75	26.50
Gyrfalcon	0.17								
Long-tailed Jaeger	1.50	1.50	1.67	1.33	1.17		0.50		
Northern Harrier	0.17								
Parasitic Jaeger	3.17	4.17	3.83	5.67	7.00	3.80	0.50	4.25	1.50
Rough-legged Hawk	1.83	2.00	1.50	1.00	1.33	1.20	2.00	1.50	3.50
Sandhill Crane	5.33	4.17	4.67	4.50	3.00	4.80	4.50	3.50	10.50
Sabine's Gull	1.33	1.00		0.50	0.67	1.00	0.50	2.75	
Short-eared Owl		0.17	0.17						
Snowy Owl				0.17		0.20		0.25	
All species	42.50	33.00	43.67	40.83	44.83	33.20	41.50	54.00	47.50

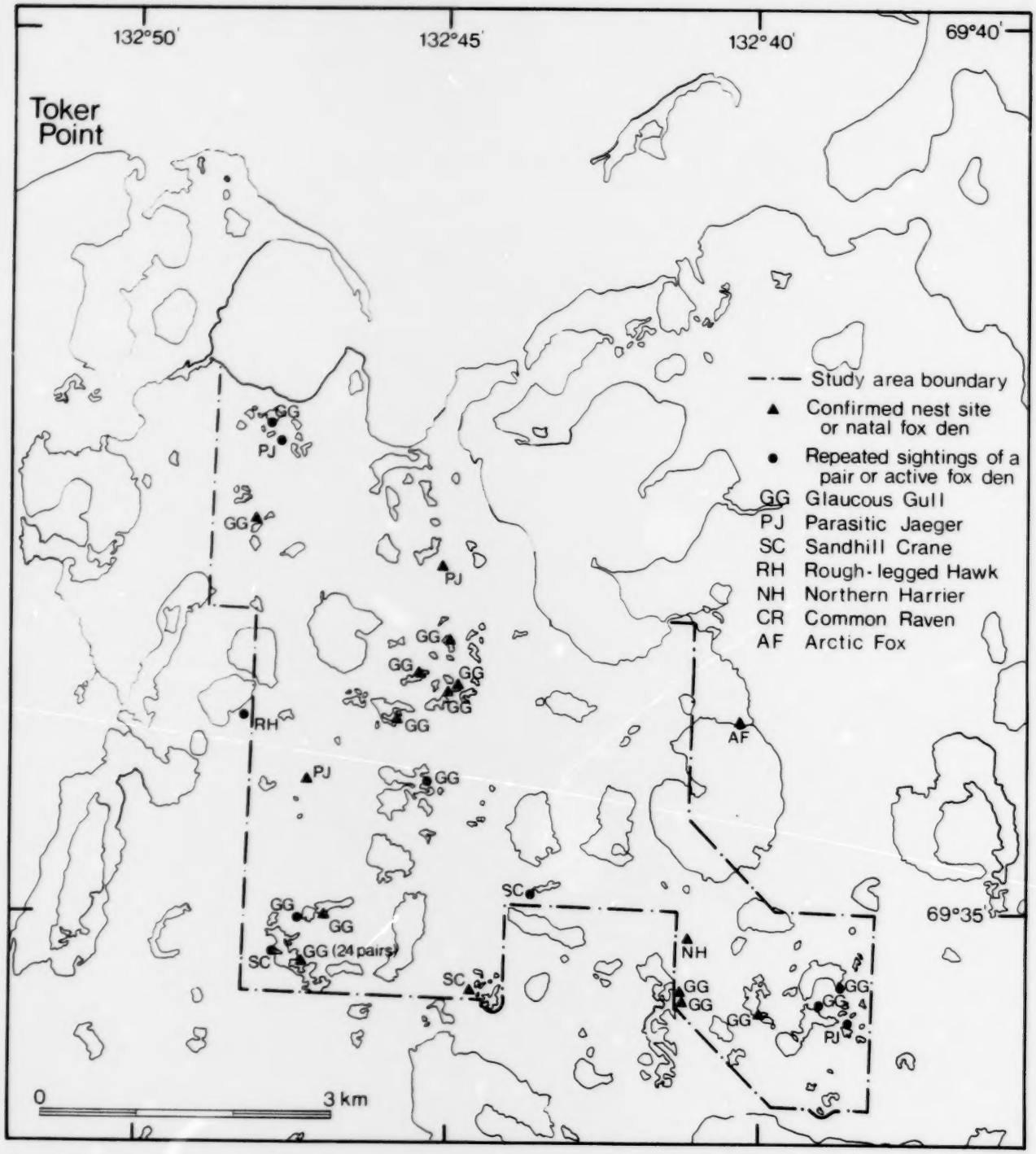
*Blank indicates 0.00

Appendix B4. Mean daily counts of predators in 1988.

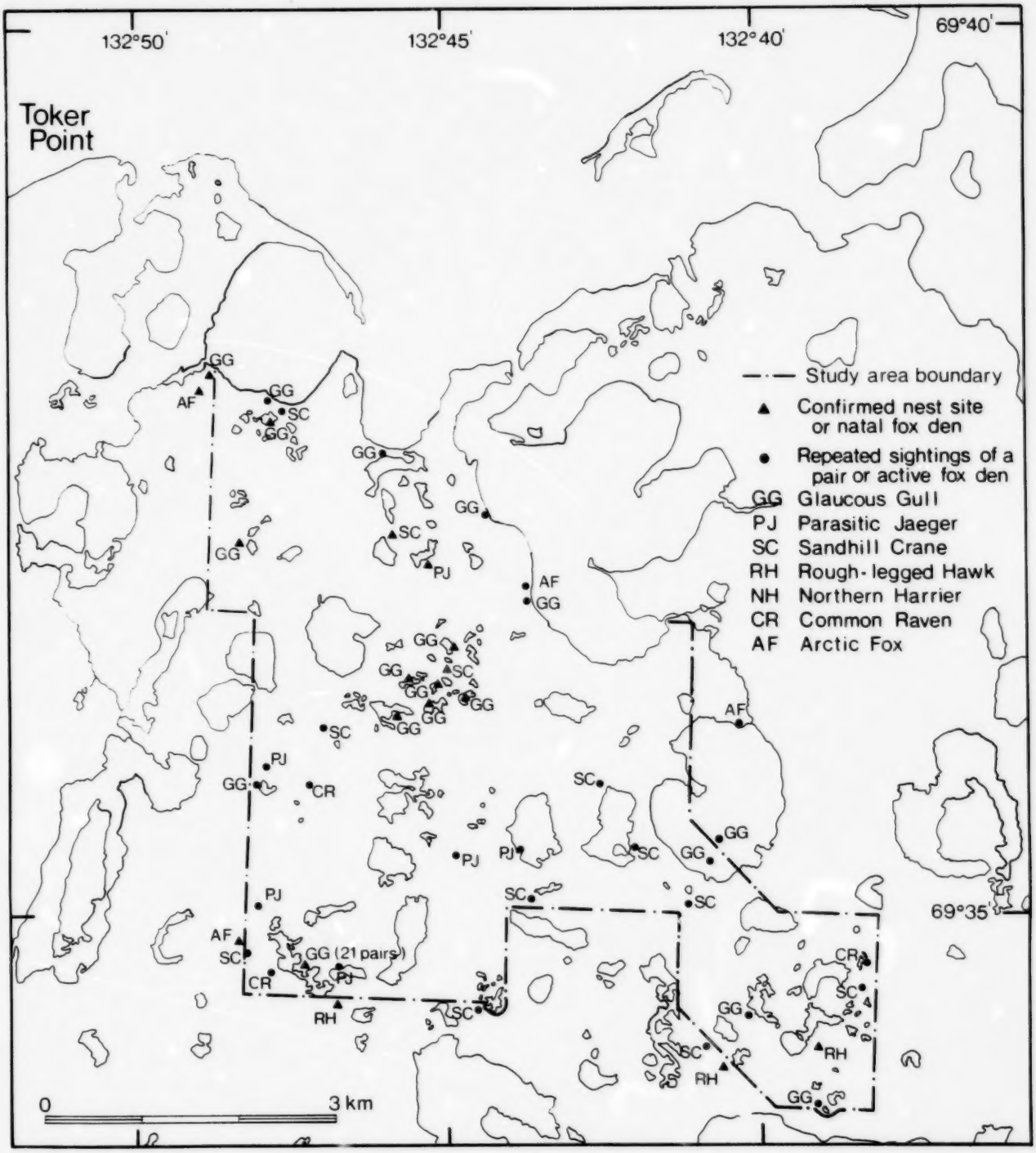
Species	Mean number observed per day by 6-day intervals								
	June 17-22	June 23-28	June 29 -July 4	July 5-10	July 11-16	July 17-22	July 23-28	July 29 -Aug. 3	Aug. 4-9
Arctic Fox	0.50				0.20				
Falcon species	0.17		0.17						
Common Raven	1.00	0.75	0.67	0.17	0.20	0.50		1.00	
Glaucous Gull	23.50	15.75	19.67	10.17	7.40	31.75	19.75	31.50	42.67
Golden Eagle		0.50							
Long-tailed Jaeger	0.83		0.33	0.17		1.00			2.67
Merlin		0.25							
Northern Harrier	1.17	0.25	0.50		0.20	0.25	0.25	0.50	
Parasitic Jaeger	3.50	2.50	1.83	3.33	2.40	3.75	2.00	6.00	6.00
Peregrine Falcon								0.50	
Pomarine Jaeger	0.17								
Rough-legged Hawk	1.67	3.50	1.83	2.50	1.80	1.75	1.50	1.00	1.00
Sandhill Crane	3.67	9.50	5.83	6.33	3.60	7.25	7.75	5.50	7.33
Sabine's Gull	0.17								
Short-eared Owl	0.83		0.33		0.20			0.50	0.33
All species	37.17	33.00	31.17	22.67	16.00	46.25	31.25	46.50	60.00

*Blank indicates 0.00

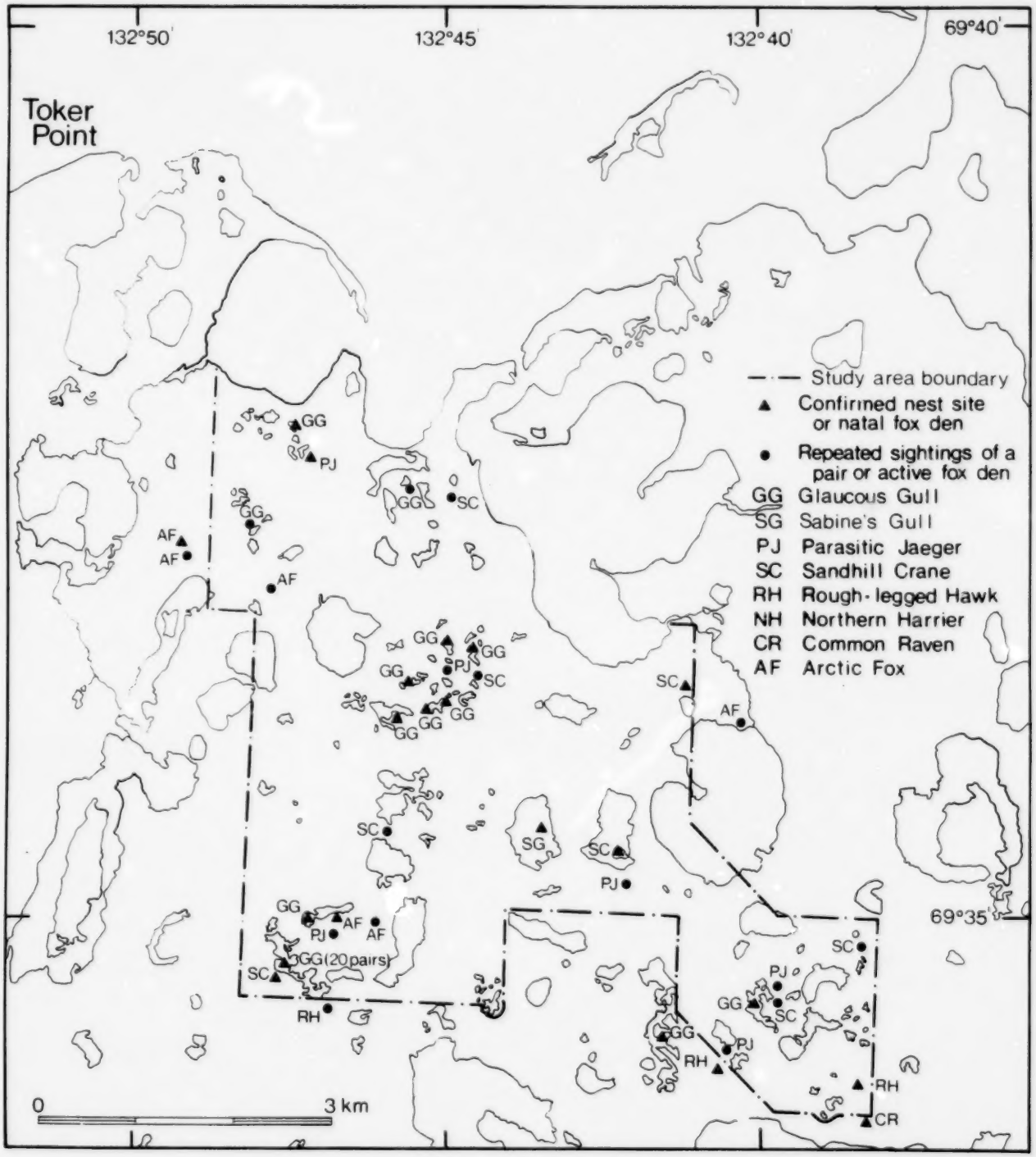
Appendix C. Location of predators each year in the Toker Point study plot.



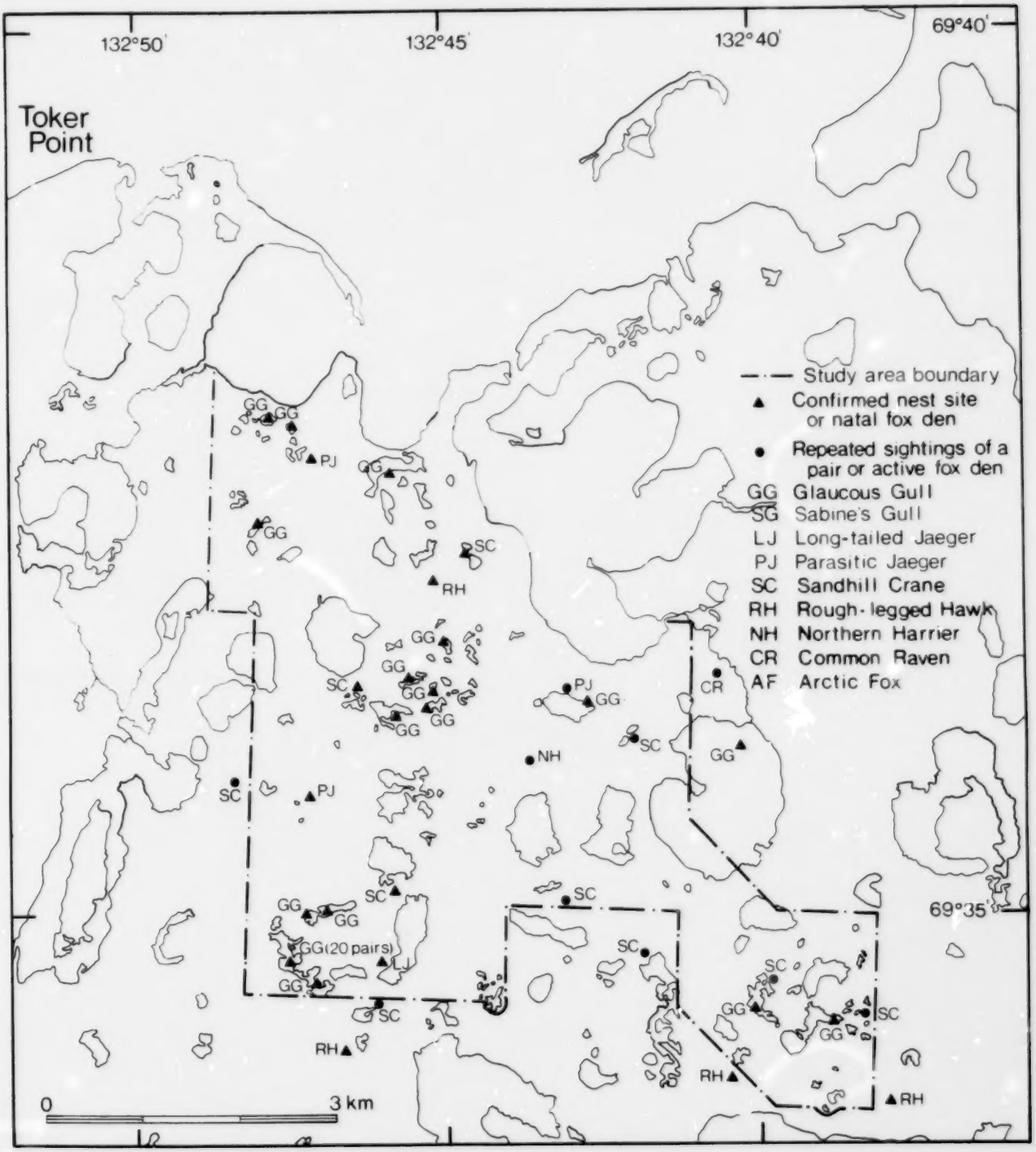
Appendix C1. Location of predators in the Toker Point study plot in June and July of 1985.



Appendix C2. Location of predators in the Toker Point study plot in June and July of 1986.



Appendix C3. Location of predators in the Toker Point study plot in June and July of 1987.



Appendix C4. Location of predators in the Toker Point study plot in June and July of 1988.

Appendix D. Number of nests, eggs and young of all birds species other than the Red-throated Loon found at Toker Point from 1985 to 1988.

Species	Number of nests[1]				Number of eggs and young[2]			
	1985	1986	1987	1988	1985	1986	1987	1988
Pacific Loon	26	17	39	34	21	6	22	23
Tundra Swan	3		5	4	27		16	31
Brant	2	1	11	2	33		15	
Greater White-fronted Goose	6	3	8	7	30	14	33	47
Northern Pintail	3	3	1	3	44	19	8	36
Green-winged Teal	1	1	1	2	19	26	15	53
Scaup sp.	3		1	1	26		8	17
Oldsquaw	3	3	6		122	52	31	122
Duck sp.				1				12
Rough-legged Hawk	1	3	3	4		9	8	8
Northern Harrier	1							
Willow Ptarmigan	3	6	4	4	78	65	30	30
Sandhill Crane	3	1	3	3	6		4	7
Lesser Golden-Plover				1	1			4
Semipalmated Plover					3			
Stilt Sandpiper	1	5	2		6	22	7	2
Long-billed Dowitcher			1	1			4	4
Red-necked Phalarope	3	1	5	6	14	2	21	26
Common Snipe	1				3			
Pectoral Sandpiper			4	1	2		16	5
Semipalmated Sandpiper	4	5	8	5	22	19	32	20
Parasitic Jaeger	2	1	1	2	1		2	4
Long-tailed Jaeger				1				
Glaucous Gull[3]	11	10	11	17	34	17	22	42
Sabine's Gull			1				2	
Arctic Tern	2		6	7	2	1	5	3
Common Raven			1					
Water Pipit			1				3	
Savannah Sparrow	3	2	18	10	15	11	89	47
American Tree Sparrow			3				11	
White-crowned Sparrow				2				9
Lapland Longspur	15	14	13	18	65	58	56	85
Redpoll sp.				15				56
Total	97	76	157	151	574	321	460	693

[1]Includes nests with eggs or young, and inaccessible nests where adults were seen incubating. For Pacific Loons, the number of active territories was used.
[2]Excludes young hatched from eggs previously recorded.
[3]Glaucous Gull colony in southwest lowland was counted as one nest each year since number of nests in colony unknown.

Appendix E. Number of small mammals trapped near Toker Point between 5 and 15 July in 1987 and 1988.

Date	Number trapped by year[1] 1987	1988
July 5	1	-
	3	-
6	2	7
	3	3
7	4	3
	2	4
8	5	3
	3	5
9	1	4
	1	4
10	1	6
	1	2
11	1	2
	3	2
12	3	4
	2	5
13	2	1
	0	0
14	2	5
	0	0
15	-	4
	-	2
Total	40	66
No./100 trapnights	4.0	6.6

[1]Traps checked at 9:00 and 21:00 hours. Recaptured animals excluded. Significant difference between years in number trapped (Sign Test, $T = 14$, $p < 0.05$).

Appendix F. Catch per unit effort (fish/100 m) of fish 5 to 20 cm long at Toker Point from 1986 to 1988.

Appendix F1. Catch per unit effort (fish/100 m) of fish 5 to 20 cm long at Toker Point in 1986.

	Species[a]														
Date	PCHA	LSCS	ARCS	BDWT	LKWT	CO	RNSM	NOPI	NSSB	FHSC	ARFL	STFL	UNID	All CO	All species
July 23 (site 5)				7.8						2.2				7.8	10.0
Aug. 3 (site 1)		23.3		3.3	1.1		12.2			6.7	1.1			27.8	47.8
Aug. 3 (site 3)		2.2	3.3	3.3			1.1				1.1			8.9	11.1
Aug. 6 (site 7)		5.6	1.1							2.2				6.7	8.9
Aug. 6 (site 6)		30.0	3.3							5.6				33.3	38.9
Aug. 9 (site 9)				3.3										3.3	3.3
Aug. 9 (site 8)		194.4	15.6		1.1		21.1			4.4	2.2			211.1	238.8
Aug. 12 (site 2)		66.7	98.0							0.7				164.7	165.4
Aug. 30 (site 4)		18.0		4.0							0.7			22.0	22.7
Mean	0	37.8	13.5	2.4	0.2	0	3.8	0	0	2.4	0.6	0	0	54.0	60.8
SD	0	62.4	32.0	2.6	0.4	0	7.6	0	0	2.5	0.7	0	0	77.5	83.4
% of catch		59	28	4	<1		5			3	<1			92	

[a]Key to abbreviations

PCHA pacific herring
LSCS least cisco
ARCS Arctic cisco
BDWT broad whitefish
LKWT lake whitefish
CO coregonid
RNSM rainbow smelt
NOPI northern pike
NSSB ninespine stickleback
FHSC fourhorn sculpin
ARFL Arctic flounder
STFL starry flounder
UNID unidentified fish

Appendix F2. Catch per unit effort (fish/100 m) of fish 5 to 20 cm long at Toker Point in 1987.

	Species[a]													
Date	PCHA	LSCS	ARCS	BDWT	LKWT	CO	RNSM	NOPI	NSSB	FHSC	ARFL	STFL	UNID	All CO	All species
July 19		0.7		5.3		18.7				1.3				24.7	26.0
July 28						1.3								1.3	1.3
Aug. 6		109.4	30.0			0.7								140.1	140.1
Aug. 12		1.3	1.3	0.7										3.3	3.3
Aug. 21		1.3	3.3	3.3										8.0	8.0
Aug. 29		3.3	2.7							5.3	1.3			6.0	12.6
Mean	0	19.3	6.2	1.6	0	3.4	0	0	0	1.1	0.2	0	0	30.6	31.9
SD	0	43.9	11.7	2.2	0	7.4	0	0	0	2.1	0.5	0	0	54.1	53.4
% of catch		61	20	5		11				3	<1			97	

[a]Key to abbreviations

PCHA pacific herring
LSCS least cisco
ARCS Arctic cisco
BDWT broad whitefish
LKWT lake whitefish
CO coregonid
RNSM rainbow smelt
NOPI northern pike
NSSB ninespine stickleback
FHSC fourhorn sculpin
ARFL Arctic flounder
STFL starry flounder
UNID unidentified fish

Appendix F3. Catch per unit effort (fish/100 m) of fish 5 to 20 cm long at Toker Point in 1988.

	Species[a]													
Date	PCHA	LSCS	ARCS	BDWT	LKWT	CO	RNSM	NOPI	NSSB	FHSC	ARFL	STFL	UNID	All CO	All species
July 17, 1988		4.7	2.0	4.7			0.7			4.0	4.7			11.3	20.7
July 24	1.3	1.3		2.7						6.0				5.3	11.3
July 30	2.0	3.3		26.7			1.3	0.7		6.7	0.7			32.0	41.4
Aug. 6	2.0	48.0	1.3	14.7	4.7				0.7	2.7	0.7			70.7	74.7
Aug. 14		33.4	1.3	6.0	1.3				0.7	2.7	0.7			42.0	46.0
Aug. 28		20.7	4.0							6.7	0.7			24.7	32.0
Sept. 3		16.0	27.3	8.7						8.0				52.0	60.0
Mean	0.8	18.2	5.1	9.1	0.8	0	0.3	0.1	0.2	5.2	1.1	0	0	34.0	40.9
SD	1.0	17.4	9.8	9.1	1.7	0	0.5	0.2	0.3	2.2	1.6	0	0	23.0	21.9
% of catch	2	44	12	22	2		<1	<1	<1	13	2			80	

[a]Key to abbreviations

PCHA pacific herring
LSCS least cisco
ARCS Arctic cisco
BDWT broad whitefish
LKWT lake whitefish
CO coregonid
RNSM rainbow smelt
NOPI northern pike
NSSB ninespine stickleback
FHSC fourhorn sculpin
ARFL Arctic flounder
STFL starry flounder
UNID unidentified fish

Appendix G. Monthly mean temperature and precipitation at Tuktoyaktuk airport from 1984 to 1988 (data provided by Atmospheric Environment Service).

Month	Temperature (°C)						Precipitation (mm)					
	1984	1985	1986	1987	1988	Norm.[1]	1984	1985	1986	1987	1988	Norm.[1]
January	-28.1	-25.4	-31.4	-23.6	-26.7	-28.4	9.5	14.0	11.0	15.1	6.6	5.4
February	-32.7		-24.0	-27.5	-25.9	-29.1	8.5		19.9	5.0	8.6	5.4
March	-27.3	-22.7	-28.7	-24.9	-21.4	-26.5	20.0	6.2	3.4	2.8	11.6	4.4
April	-14.5	-20.9	-20.6	-22.4	-12.9	-17.2	23.3	9.9	22.8	4.8	3.5	7.1
May	-3.2	-2.0	-6.8	-8.0	-4.3	-4.7	3.0	9.4	24.5	5.8	11.2	5.9
June	8.0	5.9	4.5	6.4	7.9	5.1	12.2	11.3	TR	TR	1.6	12.9
July	9.9	6.0	8.7	11.3	13.8	10.6	22.4	25.2	8.4	31.4	12.0	19.9
August	7.5	7.2	8.3	8.9	8.9	9.0	26.5	16.7	27.4	45.1	38.6	27.8
September	2.9	2.7	5.0	4.0	3.1	2.6	4.6	27.0	21.1	11.4	8.3	14.9
October	-8.6	-9.8	-7.8	-3.2	-9.3	-7.7	14.4	33.8	30.2	13.7	29.3	17.6
November	-23.5	-20.0	-24.7	-20.0	-27.5	-19.7	6.2	6.6	7.4	18.8	10.5	8.9
December	-29.1	-22.7	-23.4	-19.8	-21.5	-25.2	4.5	12.7	14.8	21.5	11.8	7.4

[1]Norm. based on 22 to 24 years of records between 1951 and 1980 at the DEW-line Site at Tuktoyaktuk.

Appendix H. Mean daily temperature at Tuktoyaktuk airport during spring thaw (data provided by Atmospheric Environment Service).

Date	1984	1985	1986	1987	1988	27-year mean
May 11-15	-6.8	-6.1	-7.4	-11.4	-5.4	-6.9
16-20	-2.1	0.0	-10.1	-9.0	-2.8	-3.9
21-25	1.1	0.1	-5.8	-7.1	-0.3	-2.6
26-30	0.0	1.8	-3.9	-1.1	2.8	0.1
31-Jun. 4	3.6	8.6	-0.5	1.1	2.7	2.0
June 5-9	8.9	2.2	0.6	4.2	4.7	3.2
10-14	10.1	0.4	1.2	1.4	8.3	5.4
15-19	8.5	3.3	4.3	10.2	6.8	5.1
20-24	9.2	8.9	10.4	9.4	9.6	6.0
25-29	6.8	12.8	10.1	9.6	12.4	7.2

Appendix I. Specimens collected and stored in the tissue bank at the National Wildlife Research Centre in Ottawa to be used as references for environmental contaminants.

Specimen number	Units in specimen	Tissue	Species	Collection date	Location
1	1	egg	Red-throated Loon	7 July 1986	69°54'N; 131°25'W
2	1	egg	Red-throated Loon	7 July 1986	69°52'N; 131°33'W
3	1	egg	Red-throated Loon	7 July 1986	69°51'N; 131°35'W
4	1	egg	Red-throated Loon	7 July 1986	69°37'N; 132°37'W
5	1	egg	Red-throated Loon	7 July 1986	69°37'N; 132°53'W
86-F1	5	whole fish	Least cisco	24 August 1986	69°37'N; 132°45'W
86-F2	12	whole fish	Least cisco	24 August 1986	69°37'N; 132°45'W
86-F3	7	whole fish	Arctic cisco	24 August 1986	69°37'N; 132°45'W
86-F4	4	whole fish	Arctic cisco	24 August 1986	69°37'N; 132°45'W
86-F5	12	whole fish	Least cisco	24 August 1986	69°37'N; 132°45'W
86-F6	9	whole fish	Least cisco	24 August 1986	69°37'N; 132°45'W
86-F7	3	whole fish	Broad whitefish	24 August 1986	69°37'N; 132°45'W
87-1	1	whole adult	Red-throated Loon	13 June 1987	69°35'N; 132°28'W
87-2	1	whole adult	Red-throated Loon	13 June 1987	69°35'N; 132°28'W
87-3	1	whole adult	Red-throated Loon	13 June 1987	69°35'N; 132°28'W
87-4	1	whole adult	Red-throated Loon	13 June 1987	69°35'N; 132°28'W
87-5	1	whole egg	Red-throated Loon	30 June 1987	69°42'N; 132°00'W
87-6	1	whole egg	Red-throated Loon	30 June 1987	69°37'N; 132°22'W
87-7	1	whole egg	Red-throated Loon	30 June 1987	69°42'N; 132°00'W
87-8	1	whole egg	Red-throated Loon	30 June 1987	69°42'N; 132°00'W
87-9	1	whole egg	Red-throated Loon	30 June 1987	69°42'N; 132°04'W
87-10	1	whole young of year	Red-throated Loon	5 September 1987	69°37'N; 132°45'W
88-1	1	whole adult	Red-throated Loon	14 June 1987	69°35'N; 132°29'W
88-2	1	whole adult	Red-throated Loon	14 June 1987	69°35'N; 132°29'W
88-3	1	whole adult	Red-throated Loon	14 June 1987	69°35'N; 132°29'W
88-4	1	whole adult	Red-throated Loon	14 June 1987	69°35'N; 132°29'W
88-5	1	whole adult	Red-throated Loon	14 June 1987	69°35'N; 132°29'W
88-6	1	whole young of year	Red-throated Loon	25 August 1988	69°37'N; 132°27'W
88-7	1	whole young of year	Red-throated Loon	25 August 1988	69°37'N; 132°35'W
88-8	1	whole young of year	Red-throated Loon	25 August 1988	69°37'N; 132°35'W
88-9	1	whole young of year	Red-throated Loon	25 August 1988	69°38'N; 132°37'W
88-10	1	whole young of year	Red-throated Loon	25 August 1988	69°38'N; 132°37'W

Appendix J. Organochlorine residues in Red-throated Loon eggs and livers collected in the Beaufort Sea region in 1986 and 1987.

	Organochlorine residues (wet weight basis) in ppm[1]			
Pooled samples	DDE	Dieldrin	Total PCBs[2]	Mirex[3]
Five eggs collected in 1986	0.582	0.037	1.62	<0.001
Five eggs collected in 1987	0.5036	0.0291	1.416	0.0108
Four livers of adults collected in 1987	0.1531	0.0151	0.5655	0.0024
Control egg 1	4.953	0.2644	10.36	0.2098
Control egg 2	5.218	0.2670	10.71	0.2112

[1]Data from Won (1986) and Won (1987).
[2]PCB47 excluded from results in all except eggs collected in 1986.
[3]Mirex = p Mirex + Mirex.

Appendix K. English and scientific names of bird species mentioned in this report.

English Name	Scientific Name
Red-throated Loon	Gavia stellata
Pacific Loon	Gavia pacifica
Common Loon	Gavia immer
Yellow-billed Loon	Gavia adamsii
Tundra Swan	Cygnus columbianus
Greater White-fronted Goose	Anser albifrons
Lesser Snow Goose	Chen caerulescens
Brant	Branta bernicla
Canada Goose	Branta canadensis
Green-winged Teal	Anas crecca
Mallard	Anas platyrhynchos
Northern Pintail	Anas acuta
Northern Shoveler	Spatula clypeata
American Wigeon	Anas americana
Canvasback	Aythya valisineria
Greater Scaup	Aythya marila
Lesser Scaup	Aythya affinis
Common Eider	Somateria mollissima
King Eider	Somateria spectabilis
Oldsquaw	Clangula hyemalis
Surf Scoter	Melanitta perspicillata
White-winged Scoter	Melanitta fusca
Common Goldeneye	Bucephala clangula
Common Merganser	Mergus merganser
Red-breasted Merganser	Mergus serrator
Bald Eagle	Haliaeetus leucocephalus
Northern Harrier	Circus cyaneus
Rough-legged Hawk	Buteo lagopus
Golden Eagle	Aquila chrysaetas
Merlin	Falco columbarius
Peregrine Falcon	Falco peregrinus
Gyrfalcon	Falco rusticolus
Willow Ptarmigan	Lagopus lagopus
Rock Ptarmigan	Lagopus mutus
Sandhill Crane	Grus canadensis
Black-bellied Plover	Pluvialis squatarola
Lesser Golden-Plover	Pluvialis dominica
Semipalmated Plover	Charadrius semipalmatus
Lesser Yellowlegs	Tringa flavipes
Whimbrel	Numenius phaeopus
Hudsonian Godwit	Limosa haemastica
Ruddy Turnstone	Arenaria interpres
Sanderling	Calidris alba
Semipalmated Sandpiper	Calidris pusilla

Appendix K. Continued.

English Name	Scientific Name
Least Sandpiper	Calidris minutilla
White-rumped Sandpiper	Calidris fuscicollis
Baird's Sandpiper	Calidris bairdii
Pectoral Sandpiper	Calidris melanotos
Stilt Sandpiper	Calidris himantopus
Buff-breasted Sandpiper	Tryngites subruficollis
Long-billed Dowitcher	Limnodromus scolopaceus
Common Snipe	Gallinago gallinago
Red-necked Phalarope	Phalaropus lobatus
Red Phalarope	Phalaropus fulicaria
Pomarine Jaeger	Stercorarius pomarinus
Parasitic Jaeger	Stercorarius parasiticus
Long-tailed Jaeger	Stercorarius longicaudus
Thayer's Gull	Larus thayeri
Glaucous Gull	Larus hyperboreus
Sabine's Gull	Xema sabini
Arctic Tern	Sterna paradisaea
Snowy Owl	Nyctea scandiaca
Short-eared Owl	Asio flammeus
Horned Lark	Eremophila alpestris
Tree Swallow	Tachycineta bicolor
Common Raven	Corvus corax
American Robin	Turdus migratorius
Water Pipit	Anthus spinoletta
Yellow Warbler	Dendroica petechia
American Tree Sparrow	Spizella arborea
Savannah Sparrow	Passerculus sandwichensis
White-crowned Sparrow	Zonotrichia leucophrys
Dark-eyed Junco	Junco hyemalis
Lapland Longspur	Calcarius lapponicus
Snow Bunting	Plectrophenax hyperboreus
Common Redpoll	Carduelis flammea
Hoary Redpoll	Carduelis hornemanni